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Toughness of Grinding Sands

by Richard C. Hoffman
GLASS DIVISION, FORD MOTOR COMPANY

● THE GENERALLY ACCEPTED THEORY of the phenomenon involved when rough plate glass blanks are reduced in dimension by the grinding action of cast iron laps using an abrasive mixture of sand and water is that the larger sand grains—at a given station in a continuous system—are dragged or rolled along the glass surface while under pressure exerted by the lap. The surface of the glass is progressively ruptured by the pressure applied from lap to glass through the sand grains. A multitude of minute fissures is thereby produced in the glass surface which causes small chips of glass to become dislodged from that surface. When the pressure on an individual sand grain becomes excessive, the grain shatters into smaller fragments which become ineffective at that particular grinding station. These same grains, however, do become the effective grinding agent at a subsequent station in the system.

In order to increase the efficiency of plate glass grinding using the conventional sand-water slurry, it is important to know the physical characteristics of the silica sands available. Such characteristics include sand particle shape, particle size distribution, and the relative toughness of the individual sand grains. Since it is the individual sand grains which do the work, their "toughness" or resistance to fracture is significant. It logically follows that the quantity of sand necessary for a given production rate is proportional to the toughness of the individual sand grains, providing the particle size distribution and characteristic particle shape are held constant. Because of the difficulties involved in evaluating various sands for grinding on a production scale or "shop trial" basis, it would be convenient if a re-

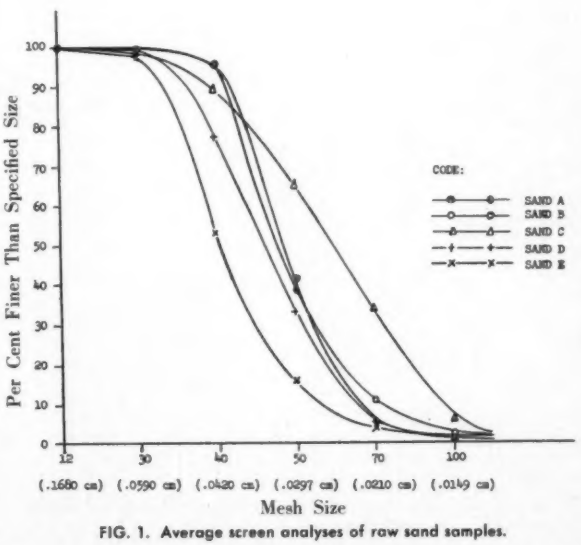

FIG. 1. Average screen analyses of raw sand samples.

producible, laboratory technique could be devised for the purpose of determining the relative toughness of potential grinding sands. In such a laboratory sand-toughness evaluation, it is apparent that any treatment should utilize the same specified particle size for each sand. One may suspect that the characteristic shape of the individual grains of a particular sand would have a significant effect on its relative toughness under a specific load due to the difference in stress distribution, etc., within the grains.

In consideration of a suitable means for determining the relative toughness of various grinding sands, a convenient method would be the utilization of a standard ball mill technique. If sand grains were reduced in size by milling, they would be subjected to a compressive load. It is probable that the rate of stress build-up in the individual sand grains would be greater than in the compressive loading of sand grains in the actual glass grinding process; however, it may be assumed that the results would at least be proportional. The "thoughness" or resistance to fracture of a material having conchoidal fracture such as quartz would necessarily be related to its increase in total surface area as a function of milling. By exposing each sand to an identical milling treatment, by calculating each resulting increase in surface area, and by relating these increases to that of a standard production sand (Michigan dune sand), a simple series of relative toughness factors could be derived as follows:

Let A_A = increase in surface area of Sand A (standard)
A_B = increase in surface area of Sand B

$$\frac{1}{\frac{A_B}{A_A}} = \frac{A_A}{A_B} = \text{toughness factor of Sand B (toughness of Sand B relative to Sand A)}$$

If the results obtained from such a ball mill technique could be substantiated by a more involved laboratory technique in which glass were actually ground, then the simpler method would suffice for future evaluations.

Procedure

Samples of five different sands from dispersed geographical locations and having different geological origins were collected, as follows:

Sand A — **Lake Michigan dune sand**
Sand B — **Ohio quarry sand**
Sand C — **Tennessee hydraulically-mined sand**
Sand D — **Tennessee river sand**
Sand E — **Illinois hydraulically-mined sand**

Screen analyses (Fig. 1) were run on all of the sands to determine the particle size most prevalent. Because all of the sands exhibited a reasonable predominance of −40, +50 mesh grains (U.S. Standard Series), this fraction was selected for the investigation. The exact milling technique was established by grinding 300-gram samples of *Sand A*, used as a standard in this investigation, for time intervals of 5, 10, and 15 minutes (Fig. 2). A 10-minute grinding cycle was selected for the investigation since it broke down approximately 50 per cent of the original grains. A Double Assay Jar Mill utilizing two one-gallon jars, each containing 30 one-inch diameter high density, alumina balls, and rotating at 60 RPM, was used throughout the investigation. The sample size in all cases was maintained at 300 grams. *Sands B, C, D,* and *E* were ground using *Sand A* as a standard for comparison. With each successive trial for each sand, the sands and mills were reversed so that any effect of the mills could be isolated. A complete screen analysis was run on each milled sample.

In order to substantiate the adequacy of the ball mill method, a parallel investigation was made in which samples of rough plate glass (3″ x 8″ x 1/8″) were ground with a floating, cast iron lap adapted to a standard drill press. The rotating speed and the load applied by the lap were held constant and approximately equal to the pressure and speed of production equipment. The grinding lap was weighed after each test, which enabled the investigator to determine the actual load applied in each case.

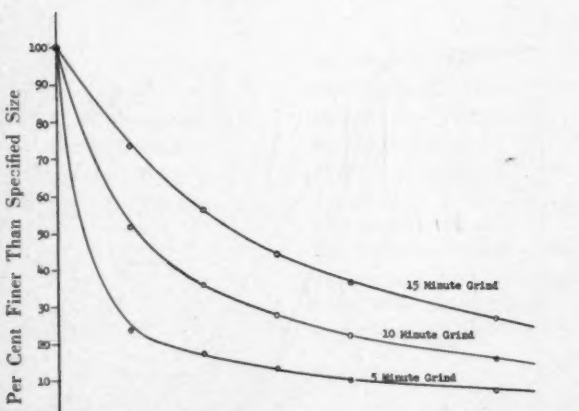

FIG. 2. Average screen analyses of standard sand after specified milling time on − 40, + 50 mesh particles.

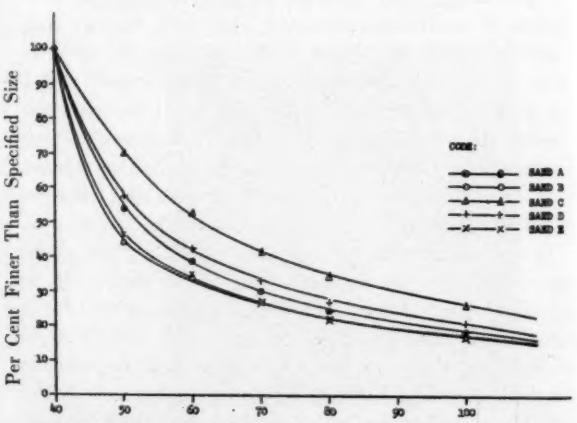

FIG. 3. Average screen analyses of sands after 10 minute milling cycle.

The grinder was equipped with a sand and water feed mechanism which allowed a constant flow of sand and water to the lap. Three hundred grams of sand and approximately 4.6 liters of water were used for each trial. At the start of each trial the sand sample was placed in the sand feed reservoir and a tube for a constant flow of tap water was placed in the water feed reservoir. Both the water and sand flow were started simultaneously by removing appropriate pinch clamps. The grinder was started at the instant the slurry contacted the glass inside the lap. In all cases, a grinding time of 3.0–3.25 minutes was used.

The apparatus was equipped with a slurry collecting system such that all grinding slurries could be retained for analysis. Each slurry sample was wet-screened through a 170-mesh sieve, dried, and subjected to a complete screen analysis. As in the case of the ball milled samples, *Sand B, C, D,* and *E* were compared to *Sand A* for particle breakdown. The amount of sand lost as compared to that used was very small. The 25 trials (5 trials for each of the 5 sands) were run in a completely randomized manner in order to minimize any effect due to time or successive treatments.

All of the sands, including the original, milled, and slurry-ground samples, were studied under a binocular microscope at a magnification of 150X.

Observations and Data

Appearance of Sands Under Microscope

1. ***Sand A*** . . . Initially spherical; presence of smooth surfaces in the larger mesh sizes (after treatment); tendency for the particles to become progressively angular with a decrease in particle size.

2. ***Sand B*** . . . Initially spherical; presence of multitude of facets on untreated particle surfaces; presence of smooth surfaces in the larger mesh sizes (after treatment); more spherical than *Sand A;* tendency for the particles to become progressively angular with a decrease in particle size.

3. ***Sand C*** . . . Initially angular; presence of sharp corners and angular surfaces in the larger mesh sizes (after treatment); presence of sharp corners and angular surfaces more prevalent than in *Sands A, B,* and *D* with a decrease in particle size.

4. ***Sand D*** . . . Initially spherical; presence of smooth surfaces in the larger mesh sizes, similar to *Sand A* (after treatment); finer sizes exhibited extremely sharp surfaces, as compared to the other sands; increased angularity with a decrease in particle size, more so than with *Sand C.*

5. ***Sand E*** . . . Initially spherical; presence of smooth surfaces in the larger mesh sizes, similar to *Sand B* (after treatment); tendency for the particles to become progressively angular decreasing in particle size.

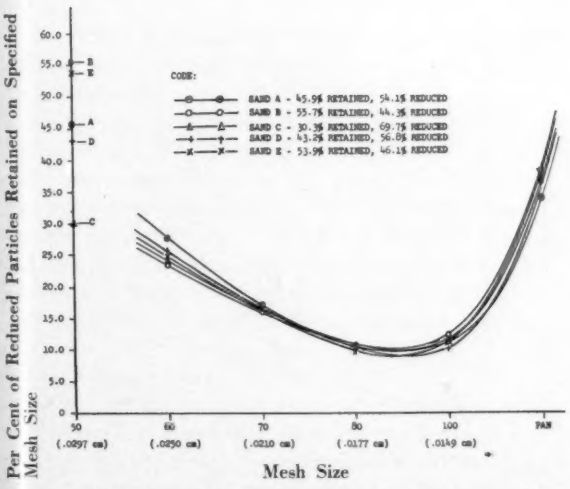

FIG. 4. Pattern of sand particle breakdown after 10 minute milling treatment.

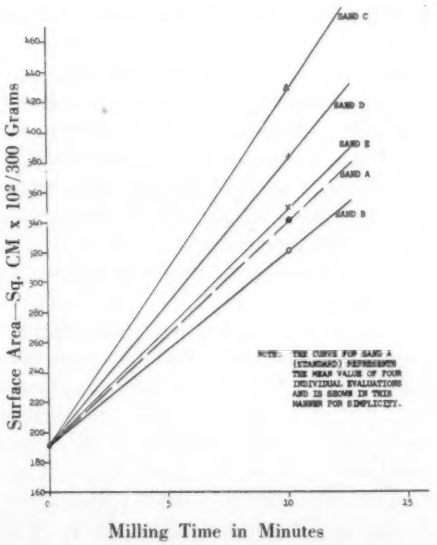

FIG. 5. Effect of ball milling.

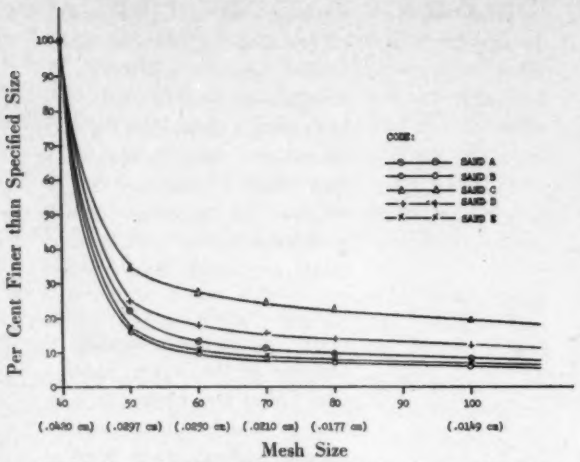

FIG. 6. Average screen analyses of sands after slurry grinding tests.

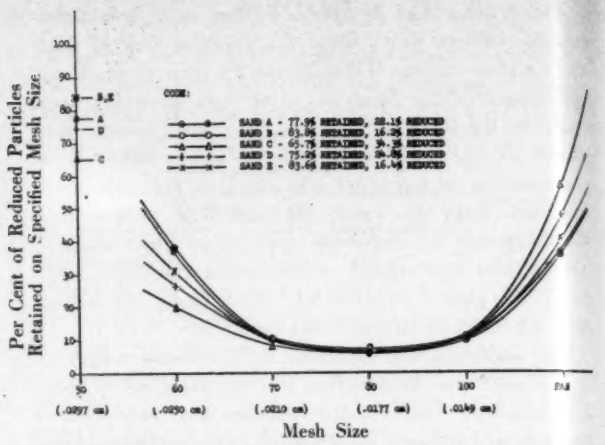

FIG. 7. Pattern of sand particle breakdown after slurry grinding treatment.

Results and Discussion

In order to correlate the results of the ball mill and slurry-grinding treatments, a series of surface area factors was calculated from the mesh openings of the U. S. Standard sieves used in the screen analyses. The total surface area of all of the 300 gram samples was calculated for each sample, before and after treatment.

Screen analyses of the ball milled samples are shown in Fig. 3, where it is evident that a difference exists between the five sands considered. It should be noted, however, that the general shape of the curves is similar in each case. A statistical analysis of the ball mill data indicated that there was a significant difference between the sands, based on their increase in total surface area.

Figure 3 clearly shows that *Sand C* was reduced to a much greater degree in overall particle size distribution than the remaining four sands. This fact indicates, that on the basis of uniform milling treatment, *Sand C* was considerably less resistant to fracture. Further, it is to be noted that *Sands B* and *D* were found to be the most resistant to particle size reduction.

It is interesting to note the particle size distribution of that portion of each sand which was reduced from the original –40, +50 mesh size. For example, as shown in Fig. 4, it can be seen that those particles which were reduced in size as a result of the uniform (from sample to sample) treatment exhibited almost identical "pattern of particle breakdown" curves.

Analyzing the ball mill test results in terms of increase in sand particle surface area (Fig. 5), it can be seen that the curve having the greatest slope represents the weakest sand, with respect to grain-for-grain toughness. *Sand C* experienced the greatest change in area as a result of the ball mill treatment, while *Sand B* was found to be the toughest having experienced an area change considerably less than that for *Sand C*.

These same considerations, when given to the data collected during the slurry-grinding tests, revealed a striking proportionality between the two methods of sand particle size reduction used in this study. Figure 6 shows the average screen analyses for the five sands as a result of the slurry-grinding treatment. Again, the similarity between curves is quite evident. *Sand C* was found to be the finest in size after the grinding treatment, while *Sand B* was found to be the coarsest of the five sands, i.e., the toughest, grain for grain.

Most prominent is the fact, however, that a comparison between screen analyses of the treated samples (Figs. 3 and 6) revealed that more of the total amount of sand was broken down from the original –40, +50 mesh size in the ball mill treatment. It should be noted that the general orientation of the curves representing the respective sands is identical for each method of sand grain-size reduction. This relationship illustrates the existing proportionality between the two treatments and their ability to reduce the over-all grain size of the sand.

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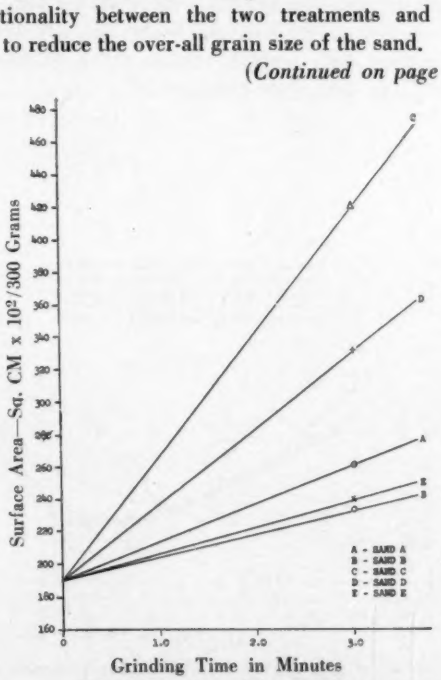


FIG. 8. Effect of sand slurry grinding.

Conditions of Glass Formation Among Simple Compounds* Part I, Conclusion

by W. A. Weyl and E. C. Marboe

College of Mineral Industries, The Pennsylvania State University, University Park, Pennsylvania

3. The Bond Strength

The concept of the bond strength or the energy of a bond between two atoms is a very useful one in discussions of the thermodynamic properties of simple molecules. The bond energies within a gaseous molecule can be derived from spectroscopic data. Thermochemical data are an additional way of obtaining values of bond energies. One can also derive the bond strength within a simple molecule by actually breaking the bond through electron impact. Using a mass spectrometer one can increase gradually the energy of the electrons and observe that energy which is necessary for breaking the gaseous molecule into fragments.

a. The Energy of Dissociation

K. H. Sun[30] (1947) made an attempt to correlate glass formation with bond strength. He based his bond strength values on the energy of dissociation of an oxide into gaseous neutral atoms. For an oxide of the formula M_mO_n, the M-O bond strength is obtained by dividing the dissociation energy of the hypothetical oxide $MO_{n/m}$ by the coordination number of the metal M. The values which were obtained by this method for the single M-O bond strength range from 119 kcal for boron to 10 kcal for cesium.

His table shows that the oxides which form glasses seem to have high bond energies (119-80 kcal), whereas the modifiers have low values of their M-O bond (60-10 kcal). Oxides with bond energies betwen 60 and 70 kcal such as Al_2O_3 are grouped as "intermediates."

A closer examination of his data, however, reveals that this system lacks a rigorous scientific basis, primarily because the coordination numbers were chosen arbitrarily in order to achieve the desired result. For example, ThO_2 and ZrO_2 at high temperatures have structures (Fluorite type) in which the metal atoms are surrounded by eight oxygens. Dividing the dissociation energies of the oxides by eight gives the value of 61 kcal for ZrO_2 and 64 kcal for ThO_2. An interpretation of these values should indicate that both oxides are intermediates, with thorium oxide having a greater tendency to participate in glass formation than zirconium oxide. This difference, however, is not supported by experiments and for this reason zirconium is given a coordination number of either six or eight, while thorium is given the coordination of eight or twelve. This arbitrary manipulation reverses the situation and places ZrO_2, but not ThO_2, in the group of glass formers.

Using the heats of dissociation of CaO and PbO and the actual coordination numbers of the metal atoms in their oxides, one obtains a bond strength of 45 kcal for the Ca-O bond and 18 kcal for the Pb-O bond. These values are in striking contrast to the actual behavior of CaO and PbO in glasses. K. H. Sun remedies this situation by assigning to the Ca atom the coordination number eight (instead of six as in CaO) and to the Pb atom the coordination number of "2" (instead of eight as in PbO).

It is an established fact that ZnO and CdO have a greater tendency than CaO to form glasses in combination with SiO_2, B_2O_3 or P_2O_5. In order to bring out this difference the Zn and Cd atoms are listed as having the coordination number of "2" rather than the higher values which they assume in crystal structures.

The values of their bond strengths bring P_2O_5, Sb_2O_5, and V_2O_5 into the group of glass formers. However, only P_2O_5 forms a stable glass: V_2O_5 and Sb_2O_5 do not. Here Sun abandons the bond strength and attributes the lack of glass formation of Sb_2O_5 and V_2O_5 as being "due to small ring formations in these substances which cause relatively easy crystallization".

The inadequacy of this approach has been noticed by those who tried to apply it to the development of new glasses. P. L. Baynton, H. Rawson and J. E. Stanworth[31] prepared a large number of glasses based on the oxides of tellurium, vanadium, molybdenum, and tungsten. These oxides cannot form glasses by themselves. However, in combination with alkalies or with P_2O_5 they can form glasses.

A paper of H. Rawson[8] gives us a good example of the difficulty which a scientist faces when he tries to understand glass formation on the basis of the bond strength. Rawson discussed the properties of new glasses which offer a very interesting structural problem. He pointed out that in the past it was customary to talk

* Mineral Industries Contribution No. 59-95.

about network formers and network modifiers. In some of these new glasses, e.g., those based on WO_3 and MoO_3, the network modifying alkalis seem to be essential constituents because they make glass formation possible. He wrote: "It is clearly important to try to explain this behavior. It may well be that in our search for explanations for glass formation in these binary melts we may throw new light on the conditions influencing glass formation in simple compounds".

Rawson went an important step beyond K. H. Sun[30] when he recognized the importance of the absolute melting point for the ability of an oxide to form a glass. He elaborates on K. H. Sun's data and calculates constants which include both the bond strengths and the absolute melting temperature T_F. In spite of this improvement he arrived at the following conclusion:

"A classification of oxides along these lines does not really take one much further than Sun's slightly simpler classification, although the former does suggest a possible reason for the extreme difficulty of crystallizing B_2O_3 from the melt, the ratio of single bond strength to the melting point in °K being particularly high for this material."

The values of the parameter "Cation-Oxygen Bond Strength/Absolute Melting Temperature" of the oxides WO_3, MoO_3 and V_2O_5 are larger than that of SiO_2 and smaller than that of B_2O_3 as can be seen from Table II.

Table II

Oxide	$B_{M^{n+}O}/T_F$
B_2O_3	0.164
SiO_2	0.053
V_2O_5	0.095
MoO_3	0.086
WO_3	0.059

Summarizing we may state that no relation exists between the ability of an oxide to form a glass and its energy of dissociation into neutral atoms, even if this parameter is divided by the absolute melting temperature.

b. Field Strength of Cations

W. A. Weyl[32] (1932) suggested that the differences in the properties of the different alkali silicate glasses might have their origin in the widely different electrical fields which the Li^+, Na^+, and K^+ ions exert upon the glass structure. This suggestion was used by K. Endell and H. Hellbrügge[33] for explaining the difference in the viscosities of fused alkali silicates of analogous compositions. A. Dietzel[34] refined this idea by using the field strength of the cations at the distance to the centers of the nearest surrounding anions and thus developed a systematic approach to the interaction of cations with their environment. Dietzel's use of the field strength Z/a^2 of a cation having the charge Z and a cation-anion distance of a made it possible to differentiate between different polyhedra, e.g., between Al^{3+} in four-fold and six-fold coordination. The usefulness of Dietzel's approach can best be judged from his success in formulating the conditions which two oxides have to meet in order to be able to form a compound. The use of the field strength enabled Dietzel to answer questions such as: Why can potassium, but not sodium or lithium, from a tetrasilicate? Why do more compounds exist in the system $BaO\text{-}SiO_2$ than in the system $BeO\text{-}SiO_2$? Dietzel gave satisfactory answers to these questions.

Dietzel makes wide use of the values of the field strength of cations. This parameter makes it possible for him to account for many properties of glasses, e.g., their thermal expansion, but he failed to establish a simple relation between the values of Z/a^2 and glass formation. In his writings Dietzel[35] adheres to the network theory of Zachariasen,[12] but he comments that this picture of a random non-periodic structure of a glass cannot explain the glass formation or even the viscosity of molten compounds. He wrote, "We are not able to see why such an irregular network does not break down at high temperatures and form a fluid melt or why a crystal of quartz or cristobalite differs from a crystal of NaCl or H_2O by not forming a fluid melt."

Dietzel plots the melting points of the oxide as a function of the field strength of the cations. This plot reveals that oxides whose cations have low values of Z/a^2, e.g., BaO (0.2), do not form glasses. The oxides which contain cations of the highest field strength, e.g., CO_2, CrO_3 and SO_3 (2.4 - 2.8), do not seem to form stable glasses either. The typical glass formers, e.g., SiO_2 and B_2O_3, have cations with an intermediate field strength (1.6 - 2.0). However, this intermediate group is not restricted to glass-forming oxides; it also includes oxides which cannot form glasses by themselves, e.g., V_2O_5 and MoO_3. The field strength of the cation does not lend itself to a classification of the oxides. Hence Dietzel turns to the use of Smekal's concept of the "mixed bond type". BaO is called ionic, CO_2 and SO_3 covalent, and the glass-forming oxides are described as having a bond type somewhere in between these two extremes.

Summarizing we may state that the field strength of a cation at the distance of the nearest surrounding O^{2-} ions can be used as a measure of the bond strength, but that this value bears no relation to the ability of an oxide to form a glass.

4. The Random Three-dimensional Network Concept

There is no difference in the properties of a substance in its crystalline and its glassy state which is sufficiently characteristic for defining the glassy state.

The mechanical strength of crystals and glasses are not very different; crystals can be stronger or weaker than glasses of corresponding compositions. The thermal expansion of a glass can be lower than that of the crystal (silica glass versus quartz) but it can also be higher than that of the crystal, (cordierite versus a corresponding magnesia alumina silica glass).

Frequently it has been emphasized that a glass, in contrast to a crystal, softens gradually and does not have a

sharp melting point. However, many crystals, e.g., silver iodide, soften gradually also and can be deformed easily below their melting points. Albite, a crystalline sodium aluminosilicate, can be held at a temperature 50°C above its melting point for days without losing its optical anisotropy and its crystalline outline. Hence, the "abrupt" change of properties with temperature in crystals as compared with their gradual change in glasses is rather problematic and does not provide a basis for characterizing the glassy state.

Attempts to define a glass by its energy content have been equally unsuccessful. It is true that most glasses are thermodynamically unstable, their energy content being higher than that of some crystalline phase of the same chemical composition. However, this does not seem to apply to glassy P_2O_5 which has a higher density than one of its crystalline modifications, is less soluble (in $CHCl_3$), and has a lower vapor pressure than the crystal.

The lack of major and characteristic differences between glasses and crystals with respect to their mechanical strength, thermal expansion, melting behavior, and their heats of formation suggests that a close structural similarity exists between glasses and crystals.

An evaluation of the role which the crystal structure of a substance plays with respect to its ability to form a stable glass was not possible before the development of modern crystal chemistry. Crystal structures by themselves cannot tell us why cristobalite, but not magnesium oxide forms a glass when the melts of the two substances are allowed to cool. No matter how fast Al_2O_3 is cooled from the molten state, one obtains corundum. No matter how slowly one cools a melt of anhydrous B_2O_3, one obtains a glass. An explanation of the differences between these oxides with respect to glass formation requires a combination of chemical and crystallographic approaches. This combination makes the problem of glass formation a crystal-chemical problem.

When Goldschmidt[29] and his collaborators performed the numerous experiments which opened up the field of modern crystal chemistry they were bound to meet with the problem of glass formation. Indeed, when Goldschmidt studied his "weakened models" of feldspars he discovered an unusual example of glass formation among fluorides.

"I discovered the tendency to glass formation in such melts as $NaLiBe_3F_8$," he wrote, "when I had these melts prepared in order to synthesize the fluoride analogues of feldspars."

This discovery aroused Goldschmidt's interest in structural factors which favor glass formation among simple systems.

a. Crystal-Chemical Approach to Glasses

It is interesting to go back to the original statements which V. M. Goldschmidt made in order to appreciate how strongly they affected the thinking of scientists with respect to the atomic structure of glasses. In 1926, Goldschmidt[29] wrote: "My experiments demonstrate that a certain ratio of the sizes of the atoms or ions and their polarization properties must be of considerable importance for glass formation.

"We find that compounds of the type AX_2 (A representing a cation and X an anion) whose radium ratios R_A/R_X are close to 0.3 and whose anions X have a low polarizability (either O^{2-} or F^- ions) have the ability to solidify as glasses and to impart this ability of glass formation to more complex melts."

After this statement Goldschmidt elaborates on these conditions pointing out that a ratio of R_A/R_X within the limits 0.2 and 0.4 favors a tetrahedral coordination of the cation. He considers it possible that the ability of substances to form glasses may be connected with the stability of tetrahedral coordinations. He elaborates further on the rule which the polarizability of the anion in the substances AX_2 seems to play in glass formation. The polarizability should be small because sulfide glasses are rare and even chlorides do not have much tendency to form glasses. Bromide and iodide glasses of the formula AX_2 were unknown.

This message had a strong impact on the thinking of the contemporary glass scientists. Firstly, Goldschmidt's findings revealed the importance of a factor which had not been stressed before, the atomic structure of the substance in its crystalline state. Secondly, Goldschmidt's findings proved that some prevailing chemical concepts were not valid. A substance did not have to be an acid in the classical sense in order to form a glass and to impart the ability of glass formation to complex melts. Before Goldschmidt no glass scientist would have expected beryllium fluoride to resemble silica in both its crystal structure and its ability to form glasses.

In addition to the conclusions which could be drawn from Goldschmidt's findings, glass scientists learned the value of crystal chemical thinking. Goldschmidt's success did not remain a purely academic one. The very practical use which H. G. Grimm and P. Huppert[36] made of crystal chemical thinking can be seen from the fact that they opened up a new field, the aluminophosphate glasses. Goldschmidt taught that in addition to the classical isomorphism a new type of structural relation exists in which the couple Al^{3+}, P^{5+} can replace 2 Si^{4+} ions.

The literature on the atomic structure of glasses and on the development of new glasses reveals how fast and strongly crystal chemical thinking penetrated into structural views and into planning new glass compositions.

b. The Rules of W. H. Zachariasen and Oxide Glasses

The next decisive step in the development of glass structures was a paper by W. H. Zachariasen[12] (1932), one of V. M. Goldschmidt's associates, who proposed certain rules which he assumed would govern the formation of oxide glasses. His paper was published in journals which were more readily accessible to glass technologists than the writings of Goldschmidt. This and the

fact that Zachariasen presented his ideas in the form of simple rules made it the basis for the structural picture which has been used by most glass technologists during the past twenty years.

Zachariasen presented a picture of the atomic structure of vitreous silica in which the silicon atoms are surrounded by four oxygens in the same way as in the different structures of crystalline silica and silicates. He suggested the structure of vitreous silica to be continuous and three-dimensional, analogous to the structures of its crystalline modifications. This means that vitreous silica does not contain individual SiO_2 molecules nor polymers such as chains. Vitreous silica according to Zachariasen's picture has a continuous, random, three dimensional structure which shows the same close range order as the crystals but does not have their long range order. The only difference between glass and crystal was the absence of periodicity: a feature which required the non-equality of the structural elements in the glass. Zachariasen wrote, "Since all atoms in glass are structurally unequivalent the energy required to detach an atom from the network will be different for each individual atom". The abrupt melting of crystals and the gradual softening which can be observed when the same substance in the glassy state is heated was considered by him to be the result of this non-equality of all structural units in a glass. Thus Zachariasen made two very important contributions to the structure of glasses. He emphasized the absence of defined SiO_2 molecules and the non-equality of the building units, atoms and polyhedra. There was a close analogy between ionic crystals and inorganic glasses inasmuch as both solids had to be treated as three-dimensional networks rather than as arrays of molecules.

For the glass-forming ability of oxides A_mO_n the following rules were derived:

1. An oxygen atom is linked to not more than two *A* atoms.
2. The number of oxygen atoms around an *A* atom must be small.
3. The oxygen polyhedra share corners but not edges or faces.
4. If we require the network to be three dimensional, at least three corners in each polyhedron must be shared.

c. *The Failure of the Network Concept*

The description of a silicate glass as a three-dimensional random network of tetrahedra which share all, or most, of their corners was simple, and it had features which were very appealing. The introduction of alkali oxides into vitreous silica loosened its structure by decreasing the average number of corners which each teatrahedron had to share with others. This feature could account for the lower viscosity of an alkali silicate glass or for its lower softening point as compared with pure silica. The classification of the constituents of a glass into network-forming oxides and those which modify the network was simple and useful. It is true that this picture had to be refined by introducing "intermediates," but for a long time the network concept seemed to provide a useful basis for theorizing on the structure of silicate and related glasses.

As far as alkali and alkali-lime-silicate glasses are concerned, the rule that the stability of their random networks depended on the number of shared corners offered a satisfactory picture within the range of commercial glasses.

Zachariasen's rules governing glass formation did not remain without criticism. His rules were based on the findings of Goldschmidt that a certain ratio of the sizes of cation and anion in a compound of the formula AX_2 is favorable to glass formation. Zachariasen assumed that a tetrahedral or a triangular coordination can be more easily distorted than one which is octahedral or higher. This means that an oxide which meets this condition has nearly the same energy content in the glassy as in the crystalline state.

G. W. Morey[37] (1934) in a discussion of Zachariasen's paper threw doubt on the correctness of Zachariasen's reasoning when he remarked: "Zachariasen has published *an interesting paper on the structure of glass. This* picture of the structure of glass seems much more probable than that of Randall, Rooksby and Cooper but, after all, does it do much more than to say in the language of X-ray structure that glass in an undercooled liquid?

"Zachariasen's further discussion is based on the assumption, also made by others, that the energy difference between crystal and glass is small, but that assumption is, as far as the writer is aware, without experimental foundation. The latent heats of melting of few crystalline silicates are known."

In the same paper Morey gives some examples. Potassium tetrasilicate is the most difficult binary silicate to crystallize, but its heat of fusion is 35 cal/gram whereas that of the readily crystallizing potassium nitrate is only 25 cal/gram.

One year later, G. Hägg[15] (1935) raised an even more serious objection to Zachariasen's approach. He pointed out that glass formation is a rate phenomenon so that its explanation has to be based on the reason for the failure of a melt to crystallize and not on the structure of the crystal. Hägg emphasized that the presence of large and irregular groups in a melt must be responsible for its failure to crystallize. In the following discussion notes [38, 39] between these two scientists, it was brought out clearly that Zachariasen did not attempt to give a general explanation of glass formation but that he restricted himself to those oxide glasses which form a three-dimensional network.

In order to understand the nearly universal acceptance of Zachariasen's rules concerning glass formation, in spite of the criticisms voiced by Morey and by Hägg, one has to remember two facts. Firstly, the majority of commercial glasses had compositions to which the rules of Zachariasen could be applied. The heavy lead

glasses were the only exceptions known at this time. Secondly, the work of B. E. Warren[40] and his school, who applied X-ray techniques for determining the atomic structures of glasses, agreed with Zachariasen's picture.

Warren's warning that his work did not prove the validity of the network theory was ignored. B. E. Warren (1941) wrote: "It would be incorrect to say that the present random network theory of the structure of glass has been uniquely established." His statement that his results could be interpreted on the basis of Zachariasen's picture was taken for proof. Warren made some very important contributions to the atomic structure of simple oxide glasses, but he also cautioned about the limitations of the X-ray method. The X-ray diffraction method has developed into the most powerful single tool for studying atomic structures of crystals, but with respect to the structures of amorphous solids it has serious limitations, as was pointed out recently by K. Grjotheim[41].

We mentioned earlier that the heavy lead glasses were the only exceptions to Zachariasen's rules. The high polarizability of the lead ion has been used by K. Fajans and N. J. Kreidl[42] for explaining the fact that the lead orthosilicate can form a stable glass. If a cation has a high polarizability, its polyhedra in the crystalline state may be highly asymmetrical because of the asymmetry of its electron cloud. One may describe a strongly polarized Pb^{2+} ion as the unit $[Pb^{4+}\ (e_2)]^{2+}$ which has a strong dipole in addition to its excess charge and, thus, explain that it can participate in the formation of a network, whereas the less polarizable cations of the same size and charge, e.g., the Sr^{++} ions, cannot form vitreous orthosilicates.[43] This explanation applies to other noble gas-like ions which are well known for their ability to enhance glass formation, e.g., the Tl^{+} and the Bi^{3+} ions.

Later developments, however, reveal the fact that stable silicate glasses can be obtained which cannot be three-dimensional networks of SiO_4 tetrahedra and which contain only noble gas-like ions.

J. M. Stevels[11] (1954) found that by proper combination of oxides, stable metasilicate glasses could be obtained, and he gives example in table III.

Table III

SiO_2	50.0	mole	per	cent
Na_2O	12.5	"	"	"
K_2O	12.5	"	"	"
CaO	12.5	"	"	"
BaO	12.5	"	"	"

He explained this "anomalous" case of glass formation as follows. "Choosing a batch with a great number of network modifiers, the 'glue' between the chains is so irregular that crystallization is prevented."

In this explanation Stevels tries to conform with the Zachariasen's three-dimensional network concept. He assumed that the metasilicate glass consisted of a network of chains which are entangled in space. The chains are negatively charged and are held together by the Na^{+}, K^{+}, Ca^{++} and Ba^{++} ions.

Most commercial silicate glasses (window, plate, and container glass) conform with Zachariasen's condition that at least three corners of each tetrahedron be shared so that not more than one corner is occupied by a non-bridging oxygen ion. In order to classify glasses, J. M. Stevels[11] and his associates introduced a structural parameter Y which denotes the average number of bridging oxygen ions per tetrahedron. The value of Y of most technical silicate glasses is of the order of 3.0 to 3.4, which means that on the average three or more of the corners of each tetrahedron are shared with other tetrahedra. A metasilicate glass has a Y value of 2.0. Glasses with a Y value of 1.0 (40 mole per cent silica) would contain on the average only pairs of tetrahedra, i.e., $(Si_2O_7)^{6-}$ anions. Further decrease of Y leads to the formation of single tetrahedra or orthosilicate anions $(SiO_4)^{4-}$. Orthosilicates, e.g., Na_4SiO_4, have a Y value of O, corresponding to 33.3 mole per cent SiO_2. Using this structural parameter Y as a measure of the coherence of the silica network, Stevels calls glasses for which the value of Y is less than 2 "Invert Glasses."

H. J. L. Trap and J. M. Stevels[11] (1959) investigated the properties of a number of invert glasses and found that silicate glasses which contain only noble gas-type cations can be obtained for which the Y value is even less than 1.0. The existence of these stable glasses which have silica ratios lower than those of metasilicate means that the concept that silicate glasses must have a three-dimenionsal network of SiO_4 tetrahedra cannot be maintained, even if the network modifiers are cations of the noble gas-type.

III. SUMMARY

We may summarize the contents of the preceding chapters and draw the following conclusions. None of the four factors which we discussed can be pertinent for glass formation. The shape factor seems to be the most logical one. One should expect the shape of molecules to play a major role and, indeed, it is the decisive factor in the formation of sulfur and selenium glasses. For vitreous silica, however, it becomes artificial to assume chains or any irregular flow unit which in the molten state has sufficient permanency to be called a macromolecule whose geometry prevents nucleation and crystallization.

The conventional classification of the chemical binding forces into several types cannot be used to account for glass formation because, with the exception of true metals, all classes of substances can form glasses. Fluoride and nitrate glasses have ionic bonds. It is customary to call the bonds between like atoms, such as in the selenium glass, covalent. Most commercial glasses are of the so-called "mixed bond type," and a large group of organic substances owe their ability to form glasses to hydrogen bonding. Van der Waals' forces are responsible for glass formation among fluorocarbons, and are active also in low-melting organic glasses and in a selenium glass.

(*Continued on page* 526)

Bibliography on Glass Structure*

PART III

59. N. Valenkov and E. Porai-Koshitz

"X-ray Investigation of the Glassy State," Z. Krist., 95, 195-229 (1936); C. A. 30, 2820 (1936).

The two fundamental hypothesis of the structure of the glassy state, (1) Warren's hypothesis of the continuous of the noncrystalline atomic network and (2) the crystalline hypothesis are discussed. It is shown that for (1) there is a sharp boundary between the glassy and the solid crystalline state; devitrification consists of the sudden breaking up of the network; diffraction patterns of glassy substances are independent of the previous history and have no maximum of higher orders (owing to absence of azimuthal regularity). For (2) there is no sharp boundary; devitrification consists of continuous growth of separate crystallites; the diffraction pattern depends on previous heat treatment and has maximum of higher orders. Powder photographs are made of crystalline and vitreous silica and soda-silica glasses subject to various thermal treatments. Comparison of the scattering curves with curves obtained by Randall's method on the supposition of crystal structure of glasses for different crystallite sizes fully justifies the crystallite theory.

60. E. Berger

"Work of W. Weyl on the Constitution of Glasses," Glastech. Ber., 13, 430-31 (1935); J. Soc. Glass Tech., 21 (83) A3 (1937); Cer. Abs. 66 (1938).

This is a discussion of Weyl's work on colored glasses.

61. B. E. Warren

"X-ray Determination of the Structure of Liquids and Glass," J. Applied Phys., 8, 645-54 (1937).

It is shown that the major part of vitreous silica cannot be in the form of cristobalite crystallites, contrary to a view held by other writers. New radio distribution curves for water at 1.5, 13, 30, 62 and 83 degrees show that each molecule has approximately four neighbors at 2.9-3.0A. It is likely that at any instant each molecule is bonded to less than four molecules; in this way the heat of fusion of ice is accounted for by breaking of some of the tetrahedra bonds in the ice structure. The density of water is greater than that of ice because the latter, in spite of its shorter oxygen-oxygen distance (2.76 A.) has an unusually open structure.

62. A. A. Lebedev

"X-ray Analysis of the Structure of Glasses," Bull. acad. sci. U.R.S.S., Classe sci. math. nat. Ser. Phys., No. 3 381-8 (1937).

An x-ray investigation of the structure of Na_2O-SiO_2 glasses containing less than 50 mol. percent Na_2O reviewed the presence of cristobalite, either alone or together with tridymite, also of Na_2O-SiO_2, the relative amounts of each depending on the ratio Na_2O:SiO_2. The size of the crystals varied between 7 and 15 A., independent on thermal treatment of the glass. The x-ray results were confirmed by determining changes in index in the glass, heated to 300°.

63. A. Gangulis

"Structure of Glass," Z. Krist., 97, 88-90 (1937).

A review of the factors involved in the formation and stability of states of matter, including glass.

64. F. Matossi

"Infrared Spectrum and Structures of Silicates and Glasses," Z. Tech. Physik., 18 (12) 585-88 (1937).

65. B. E. Warren and J Biscoe

"Fourier Analysis of X-ray Patterns of Soda-Lime Glass," J. Am. Ceram. Soc., 21, 259-65 (1938).

X-ray diffraction patterns were obtained for five compositions of soda-silica glass. The patterns were made in an evacuated camera using Mo radiation monochromated by reflection from rock salt. The patterns show a perfectly continuous change in appearance with increasing soda content. From a Fourier analysis of the x-ray scattering curves, radial distribution curves for the five glasses were obtained. The distribution curves uniquely established several important points. Each silicon atom is surrounded by 4 oxygens at a distance of 1.62 A. and each sodium by about 6 oxygens at 2.35 A. The existence in the glass of simple discrete molecules, such as silica, or soda-silica compounds is ruled out by the distribution curves.

66. J. Biscoe and B. E. Warren

"X-ray Diffraction Study of Soda-Boric Oxide Glass," J. Am. Ceram. Soc., 21, 287-93 (1938).

X-ray diffraction patterns were made of three samples

*This series will be completed next year. Reprints will be available at nominal cost, provided there is sufficient interest. Order from Reprint Dept., THE GLASS INDUSTRY, 55 West 42nd Street, New York 36, N.Y.

having varying soda-boric oxide ratios. Radial distribution curves were obtained by Fourier analysis. The first peak of the distribution curves is due to the B-O separation. The distances are 1.37, 1.42 and 1.48. From the peak areas the numbers of oxygen atoms surrounding a B are 3.2, 3.7 and 3.9 respectively. The continuous change both in inter-atomic distance and number of surrounding oxygen atoms indicates that the boron atoms are partly in triangular and partly in tetrahedral coordination. The fraction in the latter coordination increases with increasing soda content. Six oxygen atoms about each Na at 2.4 A. and 5-6 oxygen atoms about each oxygen at 2.4 A. are consistent with the distribution curves. The results can be interpreted in terms of a random network picture of vitreous Na_2O-B_2O_3 in which the B atoms are bonded to either 3 or 4 oxygens and the Na atoms occupy holes in the network. Maximum and minimum in physical properties are explained on the basis of this structure.

67. R. Thomaschek and O. Deutschbein

"The Disclosure of Glass Structure from Fluorescence Observation," Glass-Teck. Ber., 16, 155-63 (1938).

The fluorescence spectrum of europium in salt solutions, in glass melts and in crystallized glass melts were studied. The glassy state is characterized by spectrum type distinct from those obtained from the crystalline or liquid states. The nature and position of the spectral lines give definite information about bonding strength and the nature of the fields of force in the vicinity of the light-emitting atoms. Three samples of MgO prepared by various methods can be definitely distinguished by this method, though they were identical by x-ray examination. The method is thus valuable in the study of fine structure of matter. The results are all in agreement with those of Zachariasen on the structure of glasses.

68. F. Matossi

"Atomic Constitution of Glass," Z. Physik. Chem. Unterricht, 51, 71-76 (1938); Chem. Abs. 32, 5167 (1938); Cer. Abs. 325 (1938).

Structural schemes and x-ray spectra for glasses of different compositions and treatments shown in the diagrams, and references to several important papers are given.

69. F. Matossi

"Infrared Spectrum and Structure of Glasses," Helv. Phys. Acta., 11 (6) 469-71 (1938); Cer. Abs. 267 (1939).

The infrared reflection spectrum of silicate and glasses permits conclusion to be drawn regarding the atomic structure of glasses. Previous investigations are collaborated.

70. A Smekal

"Structure of Glasses and Plastics," Rev. Germ. Science, Physics of Solids, 84-101 (1939).

71. F. Matossi

"Infrared Spectrum and the Structure of Silicates and Glasses," Glastech. Ber., 16 (8) 258-63 (1938); Cer. Abs. 17 (1939).

The crystal structure of silicate is determined by the tetrahedral SiO_4 grouping which may be isolated or linked together by the sharing of 1 to 4 oxygen atoms. The infrared reflection spectrum (percent reflection plotted against wavelength) gives information concerning the extent of this linking. There is a systematic displacement of characteristic bands toward shorter wavelengths in going from an isolated tetrahedral structure, as in titanite to diopside (chain structure), to a more highly polymerized structure as in albite. In a series of BaO-SiO_2 glasses the position of the maximum shifts from 9.37 microns to 10.4 microns as a ratio of BaO:SiO_2 is increased from 0.42 to 1.36. A maximum occurring at about 12.5 microns in a spectra of crystalline silicates is ascribed to a ring structure of 4 to 6 tetrahedra. As a spectra of vitreous silica and crystalline quartz also show this band, the existence of crystallites in vitreous silica is disclosed.

72. W. Nowacki

"The Structure of Glass," Schweiz. Arch. Angew. Wiss. Tech., 4, 197 (1938).

A theoretical discussion dealing with crystal structures.

73. A. I. Kitaigorodsku

"Structure of Glass and Methods of Its Investigations by Means of X-ray Analysis," Uspekhi Fiz. Nauk, 19, 201-16 (1938).

A review. The application of x-ray analysis to glass resulted in a better understanding of the chemical composition of the latter.

74. T. Moriya

"The Fine Structure of Glass," J. Soc. Chem. Ind. Jap., 42, 746-50 (1939).

The internal molecular bonding energy was studied by means of viscosity measurements. For this purpose a special apparatus was constructed to measure viscosity in the neighborhood of the transformation temperature. The glass under examination had, at the transformation point, a viscosity coefficient of about 2.4×10^{14} c.g.s. The value for the internal bonding energy of the glass could be deduced from the trend of the straight-line graph of $\log \eta - 1/T$, which represented the magnitude of the latest heat of the fluid glass.

75. H. Moore

"Organic and Inorganic Glasses," Chem. and Ind., 58, 1027-37 (1939).

A discussion of the nature and structure of organic and inorganic glasses and their physical properties. Particular attention is given to correlating structure and properties.

76. E. Kordes

"Relation Between Fine Structure and the Physical Properties of Glasses," Glastech. Ber., 17 (3) 65-76 (1939).

Complete curves showing changes in molecular refraction with composition are presented for the following binary glass systems: SiO_2-PbO, B_2O_3-PbO, B_2O_3-ZnO, B_2O_3-CdO and P_2O_5-PbO.

77. E. Kordes

"Physiochemical Investigation of the Fine Structure of Glasses, II," Z. physic. Chem., B43, 119-52 (1939).

A number of glasses are discussed whose molar refraction can be calculated exactly from the atomic refraction of the components. These can be predicted because of special structure or special polarization effects. The molecular volume of binary, acid silicate and phosphate glasses can be calculated from consideration of their structure, together with the molecular volume of pure SiO_2 or P_2O_5 glasses and the ionic radii of the component atomic species.

78. N. Biltz

Remarks on the Paper of E. Kordes, "Investigation of the Relation Between Fine Structure and the Physical Properties of Glasses," Glastech. Ber., 17, 186 (1939).

79. E. Kordes

"Physiochemical Investigation of the Fine Structure of Glasses, I. The Molar Refraction of Binary Phosphate Silica and Borate Glasses," Z. anorg. chem. Chem., 241, 1-38 (1939).

The light refraction and specific gravity of the binary glasses of the systems B_2O_3-PbO, SiO_2-PbO, P_2O_5-PbO, and also the possible glasses of the systems B_2O_3-ZnO, and B_2O_3-CdO were determined. Curves for light refraction, specific gravity, molar volume and molar refraction are given in tables and illustrations. Compounds of the system SiO_2-PbO occurring in crystalline state were also investigated. The molar refraction of binary glasses (according to Lorentz-Lorenz) is changed in general not linearly with the molar concentration but allow more or less decided curves. Statements proposed by Biltz and Weibke for simple cases of acid glasses hold in binary systems only for the linear course of the refraction curves. Based on the concentration dependence of specific refraction a part of the O_2 atom and by use of the basic ideas of Biltz and Weibke on glass structure, relations were determined, by help of which the total refraction curves of the above glasses could be calculated theoretically and in good agreement with measurements. The same holds for the technically important glasses of the system B_2O_3-Na_2O and SiO_2-Na_2O, whose molar refractions are already known. The recent x-ray investigation of Biscoe and Warren on B_2O_3-Na_2O glasses and data obtained from their molar refraction are discussed.

80. W. Biltz and F. Weibke

"Note on the Preceding Paper on Molar Refraction of Glasses," Z. anorg. chem. Chem., 241, 39-41 (1939).

The method of calculation proposed by Kordes is questioned in view of the previous results. The molar refraction of glasses as an additive quantity; as in the refractometry of organic materials there is a relation between refraction increment and type of combination. The introduction of a variation $(MR)_O^{Si,M}$ as well as of $(MR)_O^M$ with the concentration is new and not supported by sufficient measurements. In establishing the additivity principal calculations and results were close to one another but the possibility of deviations was not excluded.

81. E. Jenckel

"Vitreous State and the Transformation Point of Glass," Z. Elektrochem, 45, 202-14 (1939); Cer. Abs. 112 (1940).

Jenckel discusses the subject of the vitreous state thoroughly under the following headings: Transition from melt to glass, nature of the internal equilibrium and the velocity of its production, and structure of glass.

82. J. Biscoe, C. S. Robinson and B. E. Warren

"X-ray Study of Boric Oxide-Silica Glass," J. Am. Ceram. Soc., 22, 180-85 (1939).

X-ray diffraction patterns were made of 4 samples of B_2O_3-SiO_2 glass (14, 30, 45 and 60% SiO_2) and of Pyrex chemically resistant glass. Radial distribution curves for the five samples were obtained by the usual Fourier analysis method. The results lead to a picture of B_2O_3-SiO_2 glass in which each Si is tetrahedrally surrounded by 3 oxygens, and each oxygen is bonded between 2 cations. In the Pyrex glass, part of the borons are probably in tetrahedral coordination. The softening of silica glass by the addition of B_2O_3 results from replacing in the random network four-fold coordinated Si by three-fold coordinated B. The low expansion coefficient of vitreous silica, contrasted with the higher expansion of crystalline silica, is explained by the impossibility of cooperative maneuvers in the random network of glassy silica.

83. O. K. Botvinkin

"Glasslike State," Izvest. Akad. Nauk. S.S.S.R. Ser. Fiz. 4, 600-603 (1940); Cer. Abs. 261 (1941).

Crystals discovered in glasses are not structural elements of them but the products of devitrification. The aggregates of simple or associated molecules composing glass are homogeneous in their chemical composition, the temperatures of complete aggregation being different for each type of grouping. Binding between molecules and aggregates of glass is considerably weaker than that between atoms in a molecule of the silicates. Tetrahedral groups (SiO_4) are connected mainly with the internal structure of the silicate molecules and not with the structure of the aggregates (with the exception of the structure of quartz glass).

84. A. A. Appen

"Glasslike State of Substances," Uspekhi Khim, 8, 1461-1518 (1939); Cer. Abs. 89 (1941).

Appen reviews a literature chiefly non-Russian. We consider the chemical compositions of glasses, the physical characteristics of the glasslike state and change the physical properties with time and temperature, and a molecular state of glasses and then discuss critically Tammann, colloidal, crystallite, and disordered-lattice hypothesis of glass structure.

85. E. Kordes

"Physicochemical Researches on the Fine Structure of Glasses III, Binary and Pseudobinary Glasses Without Appreciable Packing Effect," Z. Physik. Chem., B43 (3) 173-90 (1939); Cer. Abs. 167 (1942).

Kordes reviews the properties of several glass forming systems such as B_2O_3-SiO_2, $MgSiO_3$-$CaSiO_3$, etc.,

whose end members form glasses. In these, the mole volumes depend linearly upon composition owing to the absence of any appreciable packing effects in these glasses. They are called "coordination glasses." Fusions were prepared from B_2O_3 and As_2O_3, and specific gravities and refractive indexes were determined. In addition, vitreous Sb_2O_3 was made, and the properties of the system B_2O_3-Sb_2O_3 were investigated. In these systems, mol-refraction and mol-volume curves indicated these properties to be additives, but slight deviations from linearity were found. Kordes believes, therefore, that in the latter system some of the Sb^{+3} acts as cations. Typically molecular compounds such as piperidine and phenolphthalein form fusions whose mol-volume and mol-refraction are additive, showing the absence of packing effects.

86. R. E. Liesegang

"State of Aggregation of Glass," Glastech. Ber., 17, (9), 269-71 (1939); Cer. Abs. 43 (1940).

Liesegang briefly discusses various prevalent conceptions of the state of aggregation. Simplification would seem to result if glasses were considered to be a mixture of particles varying in size from coarse down to molecular dimensions. The molecular sizes in the viscous condition impart to the coarser aggregate are certain mobility, thus acting as a lubricant. A determination of the aggregate size distribution would be of more importance than a definition of the state of aggregation. It is no mistake to call glass "solid" if the expression "solid state of aggregation" is avoided. Classification of materials as solid, liquid, or gas is too superficial.

87. B. E. Warren and A. G. Pincus

"Atomic Consideration of Immiscibility in Glass Systems," J. Am. Ceram. Soc., 23, 301-4 (1940).

An attempt is made to apply the ideas of crystal chemistry to the problem of immiscibility in glass systems. Miscibility is favored by the tendency of the network-forming cations, Si, B, and P, to bond with all available oxygens in the melt. Immiscibility is favored in compositions which do not allow the other cations, such as Na and Ca, to be properly surrounded by unsaturated oxygens. The importance of this effect may be related to the valence and size of the cation. A qualitative discussion is given for a number of binary and ternary systems.

88. B. E. Warren

"Geometrical Considerations in Glass," J. Soc. Glass Tech., 24, 159-65 (1940).

On the basis of x-ray patterns and assumptions as to the coordination between oxygen atoms and those of Si or B, and with the ions of Na and Ca, theoretical principles are discussed governing glass vs. crystal formation; miscibility or immiscibility in glasses and anomalies in certain physical properties of glasses. The simple glasses soda-silica, lime-silica and soda-boric oxide serve as illustrations in the views expressed.

89. R. L. Muller

"The Structure of Solid Glasses According to the Data of Electrical Conductivity," Bull. acad. sci. U.R.S.S., Ser. Phys. 4, No. 4, 607-15 (in English, 615) (1940).

The exceptional role of the nature of the chemical bond of glass and its significance for the characteristics of the electrical-chemical properties of glasses are discussed. In the study of the dependence of the log of exponential electrical conductivity on the weight percentage of the oxide and of the alkali metals, there is observed an exceptionally large increase in the electrical conductivity, (10^7 x 4 K glass) beyond a definite concentration. By substituting the weight percentage content on the x-axis by volume concentration expressed in g. — ions of alkali metals per cc., a common curve is obtained for all three kinds of alkalies. At small concentrations a fan like distribution of the curves is observed at temperature intervals of 200-300°C. These temperatures correspond to the critical region of temperatures in glasses with a small content of alkali, but they lie considerably below this region in glasses rich in alkali. The electrical conductivity of glasses rich in alkali agrees with the proposed theory of electrolytic dissociation in refractory inorganic glasses containing oxygen. According to this theory the metallic cations are distributed at equilibrium in a thermodynamically nonequilibrial glasslike system, being situated near the ionized or un-ionized oxygen atoms.

90. A. A. Lebedev

"Structure of Glasses According to X-ray Analysis and Optical Properties," Bull. acad. sci. U.R.S.S., Ser. Phys., 4, 584-87 (1940).

In silicate glasses containing up to 50 mol % of soda, x-ray examination showed that 2 crystalline phases are separated from the melt, cristobalite or tridymite and sodium metasilicate. The crystallites formed in glass are 7 to 15 A.

91. K. G. Kumanin

"The Structure and Properties of Glasses From the Point of View of the Phase Rule," Bull. acad. sci. U.R.S.S., Ser. Phys., 4, No. 4, 588-94 (in English, 594) (1940).

92. I. V. Grebenshchikov

"The Structure of Glass According to Studies in the Optical Institute of the U.R.S.S.," Bull. acad. sci. U.R.S.S., Ser. Phys., 4, 579-83 (1049); Chem. Zentr. II, 1546 (1941).

Grebenshchikov defines the temperature of formation of glass, shows the analogy with the melting of rhombic S at 111-112° and with the melting of Dinas clay, deal with structural changes in glasses below the melting point and with destruction of glasses by acids and report studies with binary glasses.

93. K. S. Evstrop'ev

"The Structure of Glass-like and Salt-like Liquid Binary Mixtures According to the Data of Their Viscosity and the Electrical Conductivity," Bull. acad. sci. U.S.S.R., Ser. Phys., 4, 616-26 (1940).

An attempt is made to extend the conceptions of Lebedev-Muller of the microheterogeneous nature of solid, glass-like systems, molten glasses and liquid systems in general.

(Continued in October)

Fully Automated Lamp Making Machine

by D. A. Bogdan,
SECTION MANAGER, EQUIPMENT ENGINEERING, LAMP DIVISION
WESTINGHOUSE ELECTRIC CORP., BLOOMFIELD, N.Y.

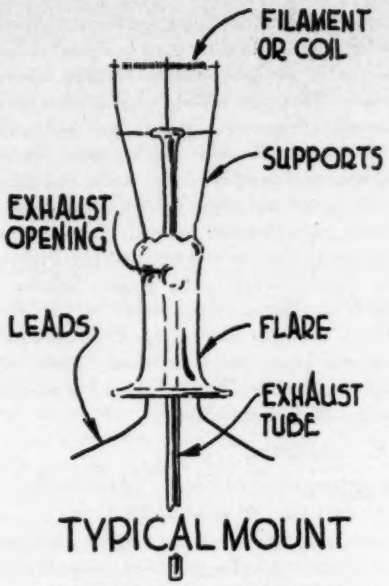


FIG. 1a. Sealing the mount into the bulb.

● WHEN A COMPANY IN THE GLASS INDUSTRY decides it must radically advance its manufacturing techniques, the problem arises as to how far to progress at once. From the conflict between confident audacity and conservative caution, Westinghouse has developed a successful philosophy nicknamed "One Step Up." Often such a step is a "giant step," yet taken with measured stride to insure not only a reasonable chance of success but that the project be accomplished in time to earn its cost and to contribute to production progress.

One of the most noteworthy developments in the Westinghouse Lamp Division equipment has been the Simplex Incandescent Group. With the first unit now in production, it is expected that its construction costs will be recouped within a satisfactory period.

This equipment is of interest to the glass industry because of the high proportion of glass used in every lamp. In the common 100W lamp, the glass purchased for each one weighs more than the finished lamp including all metal parts.

By bulk, the bulbs alone, as purchased from glass suppliers, take a volume of at least 10 times that of the remainder of the parts.

The guiding philosophy in the design of the entire equipment was to process the maximum number of pieces, with minimum attention by personnel, with the simplest design compatible with automatic handling, and with minimum waste of parts.

Parts are fed into the group simultaneously at several points:

1. Filament coils, flares, leads and glass tubing into a machine to make mounts.
2. Bulbs into bulb preparation equipment.
3. Bases into a basing machine.

They are assembled, sealed, and exhausted in a central machine known as a sealex, then based, seasoned, and tested, after which they are automatically packed.

No matter what parts are fed into any section of the group, controls are used to detect the presence or absence of any part or sub-assembly with which it is to be joined. This is accomplished by a synchronizing system that postpones feeding of subsequent parts until complete sub-assemblies are possible.

The bulbs are first prepared by coating the inner surface with a high-efficiency light-diffusing powder. First, clean bulbs are loaded into a large bin at the head of an unscrambler. The bin is of the maximum capacity possible without running the risk of bulbs crushing from their own weight; it also minimizes the number of times the bin must be attended by a server. The bulbs are then fed through a gravity controlled gate.

Because of the speed with which the glass is handled and the absence of the "personal touch" by operators, many techniques are used to prevent breakage. Slide rails are plated and polished to prevent glass parts from sticking and being broken by the next fed part. To avoid scars or strains, every effort is made to prevent sharp metal from touching glass.

A group of bulbs is passed from the load station to the coating station; rakes return them to the transport chain, where they are transferred to an overhead conveyor.

Bulbs are unloaded from the bulb conveyor automatically, but if parts for a given bulb have not been fed to another certain section of the machine, that bulb is not accepted and passes on to a reclaiming operation.

Meanwhile, "mounts" (Fig. 1A) are being made on a highly automated machine. A mount consists of a section of flared glass tubing for holding:

1. Metal parts. (Several support and lead-in wires bent into various shapes.)
2. The filament which supplies the actual light.
3. An exhaust tube through which the lamp is evacuated.

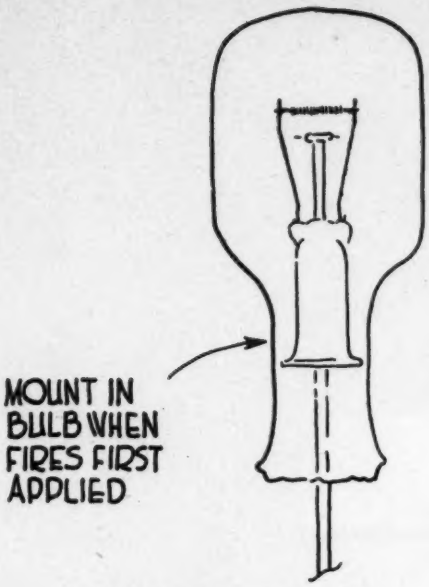


FIG. 1b. Sealing the mount into the bulb.

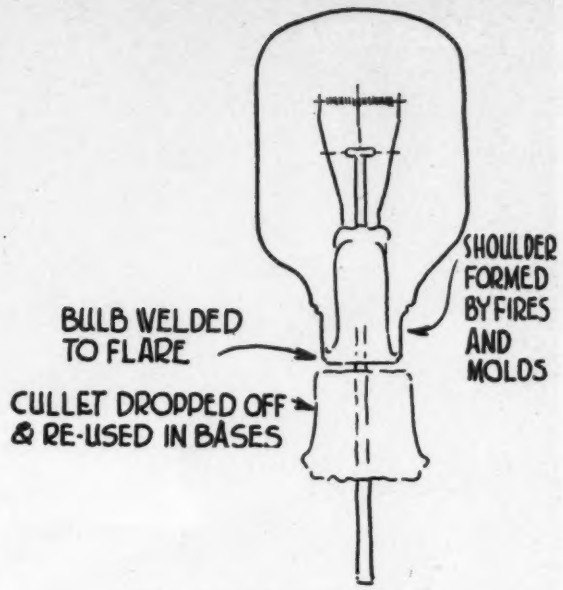


FIG. 1c. Sealing the mount into the bulb.

The mount machine contains many devices to insure that virtually no parts are wasted; however, in the control system for the entire group, allowance must be made for one characteristic of the mounting machine. If it is desired to discontinue making mounts, it is not enough to simply stop the machine, for if the heads were to remain stationary with partly completed mounts continuously exposed to intense fires, that glass might melt and damage the equipment.

When the control system, therefore, calls for stopping the flow of mounts, the machine must be allowed to discharge any mounts already in progress. To permit this, the mounts are fed into a super-flexible storage device which not only accepts excess mounts from the mount machine but also includes automatic circuits to assure a continuous supply to the succeeding machine. With the heavy investment in capital equipment, it has been felt important to keep every head working to make the product. The storage device helps accomplish this.

The feeding is coordinated so that if there is no bulb, no mount will be fed; and if there is no mount, no bulb will be fed. This requires anticipatory circuits because of the difference in number of positions between the points where the parts are fed and where they meet.

At the proper time, the coated bulbs are lowered over the completed mounts. At this point, the skirts of the bulbs extend below the flares. (Fig. 1B) Fires are applied to cut off the "cullet" which extends below the rims of the flares and to weld the envelopes to the flares. (Fig. 1C, Fig. 2.) Each bulb is now an enclosed vessel with only one opening to atmosphere, the exhaust tubing. During any operation where the glass is heated, extreme care is taken to prevent cold metal touching hot glass. Where such risks exist, the metal is faced with transite or asbestos.

After the bulbs are sealed, they approach a rotary exhaust turret on one end. The partially completed lamps are transferred by a system of rotary fingers into exhaust ports. The entrance to each port consists of a rubber plug with an axial hole connected to a vacuum system. After traveling around the exhaust machine, an automatic device tips off the exhaust tubings to seal permanently the lamps which have by this time been exhausted and refilled with nitrogen and argon.

The lamps are next transferred from the exhaust machine to a special conveyor which inverts them, and

(*Continued on page* 527)

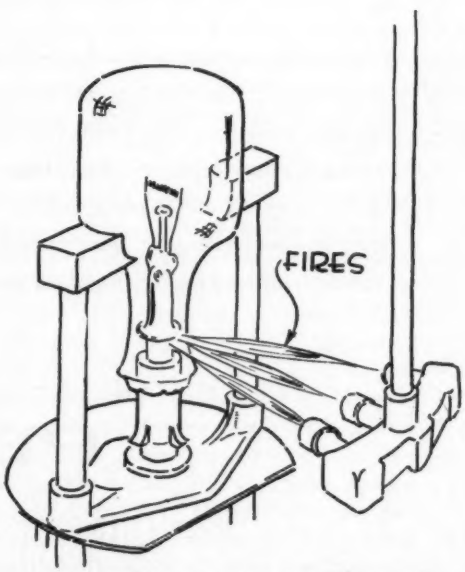
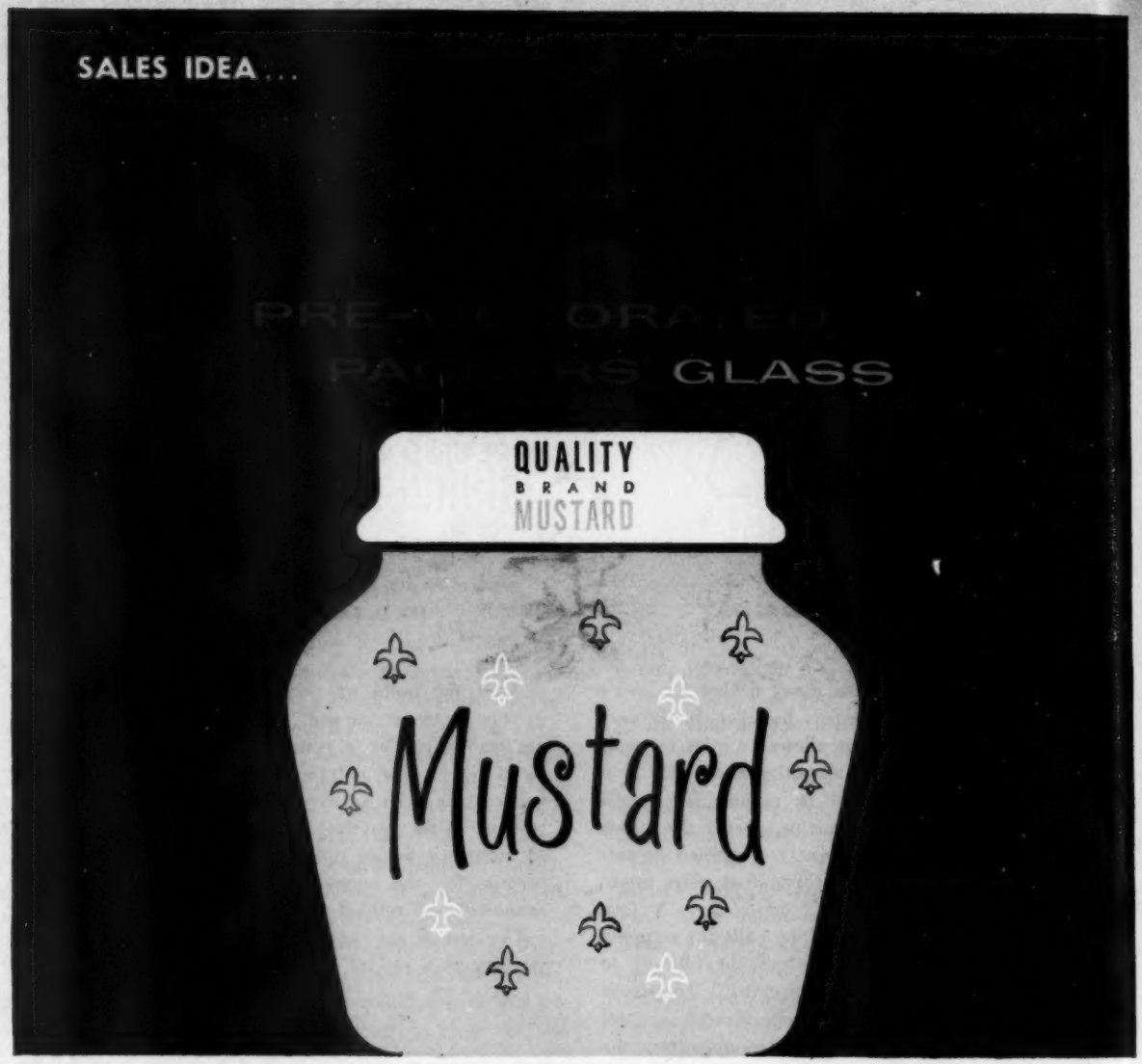


FIG. 2. Holding the mount and bulb while sealing.

SALES IDEA...



Offer your customers a built-in sales advantage... attractive, pre-decorated bottles and jars for mustard, catsup, pickles, mayonnaise, etc., that will grace any homemaker's table. This bright idea will give your customers' products the edge they need on shelves to promote extra attention and sales. It will give you the edge you can use to earn a greater share of the package dollar.

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50 YEARS OF RESEARCH AND A FLAME

PEMCO CORPORATION

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CERAMIC FRITS, INORGANIC PIGMENTS, VITRIFIABLE GLASS COLORS

Courtesy Douglas Aircraft Corp., Inc., Santa Monica, Calif.

Douglas-Air Force C-133A, one of the largest cargo transports now in quantity production, is flown under all weather conditions. According to the book "Silicones," by R. N. Meals and F. M. Lewis, "metal anti-icing ducts in leading edge of wing are covered with fiber glass insulation and an external cover of silicone-coated fiber glass. . . . Insulation protects aluminum structure in skin of airplane from high-temperature air within ducts." Ducts are used to distribute heat to the de-icers.

SILICONES in the Fiber Glass Industry

by J. Sidlovsky, SILICONES DIVISION, UNION CARBIDE CORPORATION, TONAWANDA, N. Y.

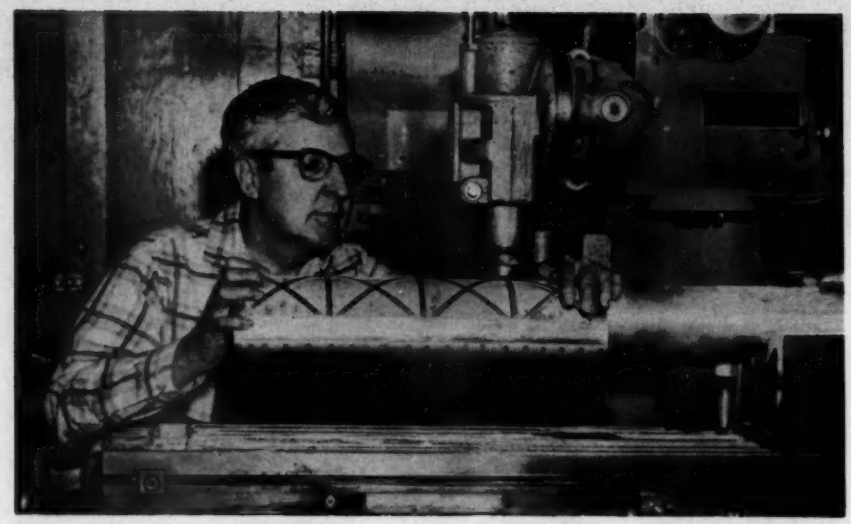
● OVER THE PAST 15 YEARS, the glass industry has become familiar with silicones as invaluable aids in glass manufacture. Their main uses have been as release and anti-seize agents*. Silicones also play a large part in the fiber glass industry. But here, in contrast, it is the bonding properties of a special class of silicon-containing chemicals that have made them particularly valuable—primarily in the application of glass fibers as reinforcement for plastics.

To be accurate, we say "silicon containing chemicals" or "silanes" rather than "silicones." Silanes are monomeric chemicals that can be reacted to form silicone polymers. The special class of silicon-containing chemicals referred to are called organo-functional silanes. By organo-functional, we mean that the organic portion of the silane has been designed to be reactive with organic materials, including plastics. It is this reactivity which makes them useful to the reinforced plastics industry.

Perhaps the earliest important applications for glass reinforced plastics were as strong, light-weight structural elements for military aircraft. The early polyester glass laminates showed great promise, exhibiting strengths superior to structural steel or aluminum of the same weight; however, serious drawbacks were encountered. Exposure to high humidity greatly decreased the strength of the laminates; water penetrated by capillary action into air spaces between the fiber and the resin. The bond was weakened and the mechanical properties were as much as 50 per cent lower after exposure to water.

A related drawback was found when high temperature phenolic resins came into use. In this case, while it was known that phenolic resins and glass cloth have excellent mechanical properties at 500° F., phenolic-glass laminates showed almost complete loss of strength at these temperatures. It was reasoned that the fault lay in the interface between the two components—specifically, that oxidative deterioration occurred as a result of the air on the exposed surfaces of the glass fibers in the capillary spaces. Consideration of the dually reactive nature of the organo-functional silanes led to research into the eventual development of glass coupling agents which would bond these resins to the glass and improve resin-

*See "A Report on the Use of Silicone Lubricants at Wheaton Glass Company, by Thomas W. Bailey. GLASS INDUSTRY, 38 (8) 433, 1957.



Official U. S. Army photograph/Released by Department of Defense, Washington, D. C.

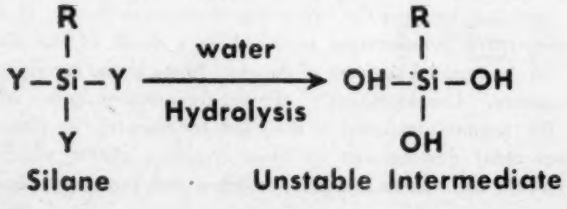
A glass fiber lattice sleeve for holding instruments of a satellite launched in 1958 by U. S. Army's Jupiter C at Cape Canaveral, Fla., is being machined at the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Calif.

wetting properties so that the capillary spaces would be eliminated.

The early research into the field was concerned with silanes and silicones containing vinyl groups having chemical reactivity with unsaturated polyester resins. The first coupling agents developed were difficult to use because the silane compounds contained chlorine groups which liberated HCl during the glass fiber treating process; the silicone materials overcome the objection of the presence of HCl, but unlike the silanes, curing temperatures as high as 530°F. were required to obtain a good bond to glass fiber. These drawbacks were sufficiently severe as to encourage further research toward finding a suitable coupling agent. This was finally achieved with the development of a non-corrosive, water-soluble vinyl silane ester. The water solubility is due to hydrophilic ester groups in the silane molecule.

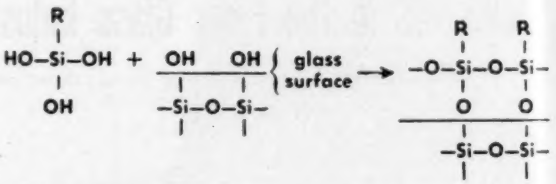
Concurrent research was conducted toward development of an organo-functional silane for use with phenolic, epoxy, or melamine resins. Success was achieved with the production of a *gamma*-aminopropyltriethoxy-silane. This chemical is also water soluble because of the primary amine portion of the silane molecule. A simplified account of how these products react with glass and plastic to form a chemical bridge between these two incompatible materials can be presented diagrammatically:

1. The water-soluble coupling agent is diluted with water, and hydrolysis takes place.



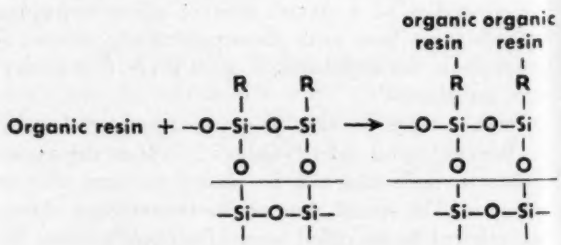
R is either a Vinyl group
or
An Amine containing group
Y is an ester group

2. After hydrolysis, the coupling agent is applied to glass and dried. The SiOH groups of the glass react with the SiOH groups of the finish.



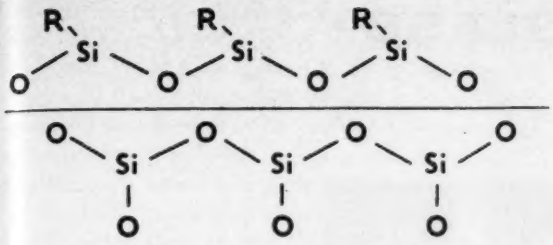
Or there is oriented chemisorption of a cross-linked polymer.

Thus forming the first half of the chemical bridge.



3. The treated glass now has numerous groups ready to react with the organic resin. (See next page)

If *R* is the vinyl group, it will react with the unsaturated organic resin, forming the second half of the chemical bridge. Thus, a vinyl silane is used with polyesters.



If *R* is the amine-containing group, the amine reacts with the polar groups of organic resins such as epoxies, phenolics, and melamines, forming the second half of the chemical bridge. Thus, *gamma*-aminopropyltriethoxysilane is used with these resins.

Glass cloth is coated with these silane-coupling agents, using conventional textile treaters and drying equipment. A treating solution of the coupling agent is prepared by dissolving one to two per cent of the silane into water, and a basic catalyst, such as morpholine, is added to the vinyl silane ester solution to speed up hydrolysis of the esters group. No catalyst is added to the amino silane ester solution since it is adequately basic because of the presence of the amine group. The glass cloth is then processed through the treating solution, a padder (to remove excess solution), and through a drying oven. The processing is accomplished as fast as the water can be evaporated from the cloth.

Heating towers vary in design. They may be vertical or horizontal, single or multiple pass, and heated either electrically or with direct or indirect gas combustion. The glass cloth is then wound into rolls for shipment.

It may seem strange to employ a water-soluble coupling agent for the purpose of excluding water in the final product; however, this is easily understood if it is realized that the hydrophilic portion of the vinyl silane ester is hydrolyzed and evaporated from the cloth during the treating process, and that the hydrophilic portion, the primary amine, of *gamma*-aminopropyltriethoxysilane is reacted with phenolic, epoxy, or melamine resins.

While up to now we have been speaking of glass fabrics, these coupling agents, because of their water solubility, are also easily adopted for use in binder sizes. A binder is a resin added to mat or glass wool to give it structural strength. These are not used for laminating, but rather for such large-volume applications as insulating batts for buildings, refrigerators, and many other applications. The silane can be applied either to the glass or mixed in with the resin system.

Physical Properties and Applications

We have spoken in chemical terms of the effects of the silane finishes upon glass reinforced plastics. The most important way, however, in which to speak of these effects is in physical terms. Table I compares strengths of polyester glass laminates made using, in the first case, a water-soluble vinyl silane finish and, in the other, heat-cleaned glass cloth. The effectiveness of this silane treatment to glass and of its complete miscibility with the polyester resins can be demonstrated graphically by observing the passage of light through the laminate.

Laminates made with unfinished glass are much less translucent. This is most likely a consequence of the capillary spaces between the resins and the glass, since in a laminate of this type there are thousands of glass-resin interfaces per square inch. Sufficient light is scattered to make the laminates appear opaque. If these laminates are placed in an aqueous dye solution, the dye penetrates the glass fibers and can easily be seen. When the vinyl silane is applied to the glass, nearly transparent laminates can be prepared, because the light scattering interfaces between resin and air, and air and glass, are eliminated.

Only the fact that the resin and glass have slightly different refractive indices prevents the laminates from being completely transparent. Even so, newsprint can easily be read through these laminates. The wet strength retention, as depicted by optical and physical properties of laminates immersed in water, is vitally important in many of the most widespread uses of polyester laminates. Among these uses are included boat hulls, submarine fairwaters, highway trailers and motor cabs, sports car bodies, corrugated outdoor panels and fishing rods. Silane finishes for glass are also an asset in fiber glass reinforced plastic pipe, tooling, decorative parts for railway cars, shower partitions, tote boxes, acoustical tile, furniture to give a few examples.

Table I, (A, B, and C.) gives comparisons of fiber glass laminates of phenolic, epoxy, and melamine resins, respectively, using heat-cleaned glass (starch and oil

(*Continued on page* 524)

Table I

GLASS FIBER REINFORCED LAMINATES

Polyester Resin	Flexural Strength, psi* Tested at Room Temperature	Tested after Boiling in Water for 2 Hours
No Treatment	60,000	35,000
Water Soluble Vinyl Ester Treatment	75,000	70,000
A		
Phenolic Resin*		
No Treatment	69,000	40,000
Gamma-aminopropyltriethoxy-silane Treatment	85,000	80,000
B		
Epoxy Resin		
No Treatment	73,600	53,500
Gamma-aminopropyltriethoxy-silane Treatment	81,000	75,000
C		
Melamine Resin (Electric Properties)		
No Treatment	38,000	27,000
Gamma-aminopropyltriethoxy-silane Treatment	90,000	85,000

*After 100 hours' exposure at 500°F., the flexural strengths of phenolic laminates containing no finish and containing *gamma*-aminopropyltriethoxysilane are 14,000 and 50,000 psi respectively.

*These figures are the results of specific tests made at the laboratories of Silicones Division, Union Carbide Corporation, Tonawanda N. Y.

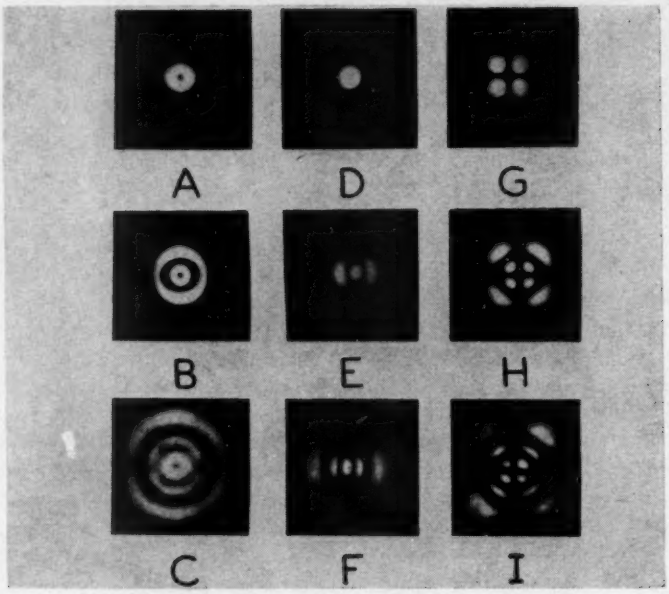


FIG. 1. Transmission mode patterns in optical fiber wave guides. (The nine lowest order modes are represented.)

Fiber Optics

by Dr. Walter P. Siegmund, Assistant Director of Research, American Optical Company.

Dr. Siegmund is responsible for the development program in fiber optics at American Optical Company. He is a graduate of the University of Rochester where he received both his A.B. and Ph. D. degrees. Before entering the field of fiber optics in 1953 he worked on the development of the TODD-AO motion picture system.

● ULTIMATELY VIEWING THE INTERIOR of the human heart is only one of the many intriguing uses suggested for glass fibers in the new branch of optical technology — fiber optics. Recently during the fifth Annual Technical Symposium of the Society of Photographic Instrumentation Engineers, representatives of both the optical and electronic industries took part in a seminar devoted to the discussion of current problems and numerous applications of fiber optics.

It is hoped that this article, a review of the seminar and a report on some additional applications incorporating fiber optics, will give some indication of the potential usefulness of this new optical tool.

What is Fiber Optics?

Fiber optics is based on the property of fibers of glass, quartz and certain plastics to transmit light by multiple internal reflections along their walls. Under ideal conditions light may be transmitted along such fibers for one hundred feet or more. When a large number of optical fibers are gathered together in a systematic manner, the resulting fiber bundle is capable of transmitting an optical image as well. Image-transmitting fiber bundles can be long or short, slender or thick, flexible or rigid. In general, only the long, slender bundles are very flexible, and short bundles of large diameter are usually fused together to form a rigid fiber optics win-

dow. Another class of fiber bundles called *image transducers* has their component fibers arranged differently at both ends. The shape or appearance of the image transmitted with such a bundle will be altered according to the relative arrangement at the two ends. Because of the large number of possible configurations, this form of fiber bundle introduces an entirely new degree of freedom into the design of optical systems.

Still another class of fiber bundles called *light pipes* has no prescribed arrangement of the fiber ends whatever except that they are clustered together to minimize the lost area between the fibers. Such bundles are used where it is necessary only to transmit light and not an image.

Fiber Optics Seminar

The theme of the seminar was "Recent Advances in Fiber Optics" with emphasis on the application of fiber optics to various photographic instrumentation problems. Following a brief introduction of the panel members by the moderator,* the fundamental principles and properties of optical fibers were reviewed by Dr. N. S. Kapany, Armour Research Foundation, Chicago. Describing the optical behavior of fibers in terms of both geometrical optics and physical optics, Dr. Kapany illustrated that some of the properties of optical fibers, including the manner in which light is transmitted through straight, curved and tapered fibers, can be adequately explained by geometrical or ray optics, i.e. by assuming that light travels through the fiber in discrete rays. For example, the nominal light-gathering power or "numerical aperture" of an optical fiber is conveniently defined by the steepest meridional ray which the fiber can transmit, although such a ray is only a mathematical concept.

But not all of the optical properties of fibers can be understood, however, by the ray concept. When the diameter of the fiber is made very small, approaching a few wave lengths of light, some interesting phenomena occur which can only be explained by physical optics, i.e. by treating light as an electromagnetic wave and the fiber as an optical wave guide.

If one illuminates one end of a fiber with white light and critically examines the other end with a microscope, one finds that for large fiber diameters the end usually appears as a bright disc uniformly filled with light, but for small fiber diameters a pattern of colored spots of light will be seen instead. The particular pattern seen will depend on the size and shape of the fiber and the mode of illumination. These patterns correspond to various wave-guide transmission modes analogous to those of micro-waves traveling in a dielectric wave guide. Dr. Kapany showed a series of colored photographs of various transmission modes in clusters of small fibers. Theoretical and experimental studies of these phenomena are currently being carried out by Dr. Kapany and by Dr. Elias Snitzer, American Optical Company. A set of photographs made by Dr. Snitzer of the lower order transmission mode patterns is shown in Fig. 1.

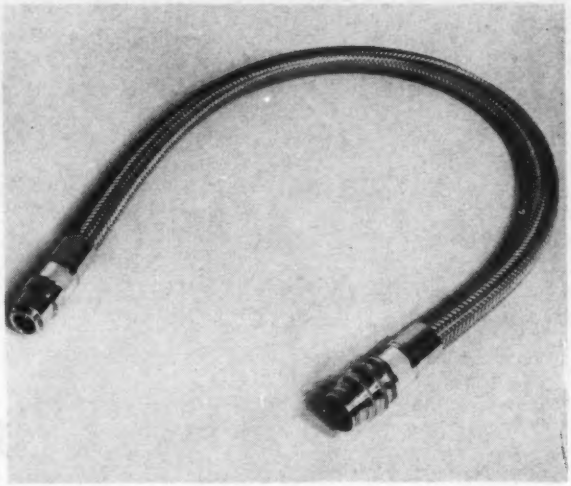


FIG. 2. Flexible "fiberscope"—This instrument is about one inch in diameter and three feet long.

Optical wave guides were accidentally "discovered" at American Optical Company several years ago when a technique for making very small optical fibers was being developed. It was only a laboratory curiosity when a research program was initiated to study the phenomena in detail. Started as a piece of pure research, this study now holds promise of important practical results as well in the field of optical masers. These are devices capable of amplifying electromagnetic radiation by the mechanism of stimulated emission. They have been operational for some time for the microwave spectrum but have only recently been demonstrated for the optical spectrum. One promising approach to an optical maser, which is now being investigated by Dr. Snitzer involves the use of optical wave guides acting as mode selectors, a concept derived from the earlier basic study.

Fiber Coating

Another aspect of the transmission properties of optical fibers was described by Dr. J. S. Courtney-Pratt, Bell Telephone Laboratories, Murray Hill, New Jersey. When optical fibers are bundled together, it is possible for light to leak from one fiber to the next wherever the fibers touch or closely approach each other. Techniques have been described by Dr. Kapany and others for coating fibers with a transparent layer of lower refractive index glass or plastic to optically "insulate" the fibers from one another and at the same time to protect the reflecting interface from contamination and abrasion. Such coatings effectively prevent leakage of light between neighboring fibers so long as the rays in the fibers are not too steep, i.e. beyond the critical angle of total reflection at the interface. Steeper rays will still leak out among the fibers and emerge as stray light, thereby reducing the transmitted image quality in certain applications. As a means for reducing such stray light, Dr. Courtney-Pratt considered the use of light-absorbing

* Dr. Siegmund, the author.—Ed.

FIG. 3. Fiber optics window for a vidicon camera tube. This window contains approximately one million fibers.

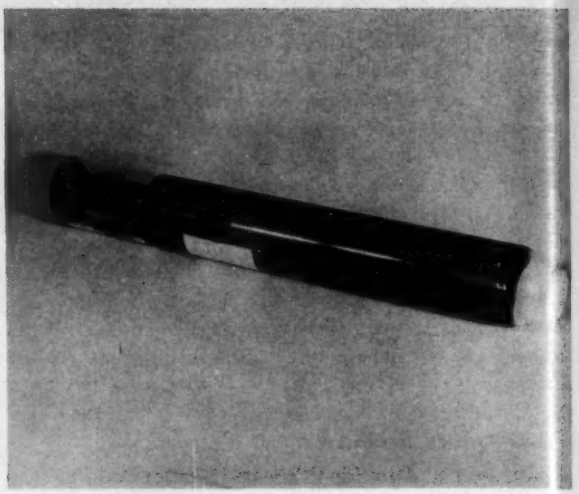


FIG. 4. Experimental recording cathode-ray tube fitted with a fiber optics window.

coatings on the fibers. To determine the effect of various combinations of indices of refraction of the fiber core and the coating, absorption of the coating, diameter and length of the fiber, etc., he set up the complete problem on an IBM computer and solved a large number of cases, the results of which were presented graphically. For applications in which the fibers are comparatively short, such as fiber optic windows, he found that a controlled amount of absorption in the coating did improve the ratio of useful light to stray light transmitted.

Transmission Efficiency

The problem of measuring the transmission efficiency of actual fiber assemblies was discussed by William Fujimura, Bausch & Lomb, Inc., one of the nation's oldest optical companies and one which has been engaged in the development of fiber optics for several years. The specific problem was to standardize on a method of measurement which would afford comparisons of various fiber bundles and, ultimately, control of the quality of the manufactured product. To this end they have built up a specialized photometer bench which was described in detail. Since this instrument had just been completed at the time of the meeting no results of measurements on representative fiber bundles were reported.

The remainder of the seminar was devoted to a discussion of a number of applications of fiber optics in various stages of development. The seminar had already exceeded its time limit when a suggestion was made from the floor that another meeting be scheduled to continue the discussion. Consequently, another session concerning applications and lasting over 1½ hours was held later the same day.

Recording Applications

The discussion of specific applications was led off by Leo J. Krolak, Radio Corporation of America (Defense Electronics Products), Camden, New Jersey. The first of three applications he described was a new form of motion-stabilized, airborne television camera system. At present, it is necessary to stabilize the entire TV camera with expensive and cumbersome gimballing equipment. In the new approach a flexible fiber bundle is used between the camera and the lens so that only the end of the fiber bundle with the objective lens need be stabilized, and smaller gimballing equipment can be employed.

In this application two types of fiber bundles were utilized. To provide the flexible coupling between the stabilized lens and fixed camera a flexible type bundle of fibers 24 inches long was procured. The component fibers in the bundle were cemented together in precisely the same arrangement at both ends of the bundle but were left loose and free to flex and twist in between. The fiber bundle was enclosed in a metallic sheath to protect the fibers from accidential breakage. The individual fiber elements were 15 microns (.0006″) in diameter, and the bundle contained approximately 350,000 elements. Figure 2 shows a similar fiber bundle 36 inches in length with an objective lens at one end (Bottom) and an eyepiece at the other (Top) to view the transmitted image. Such a flexible telescope is often referred to as a *fiberscope*.

The other form of fiber bundle used in this application was a fused fiber optics window sealed to the vidicon tube in place of the usual face plate to transfer the image from the end of the flexible bundle to the photocathode surface. Windows of this type are prepared by fusing together a large number of glass-coated, high-refractive index glass fibers into a vacuum-tight disc or plate, the faces of which are then polished flat or curved to match the image surface. In this case, the window was designed to fit the RCA Type 7038 Vidicon Tube but was made 50 per cent thicker for added strength. The window contained approximately 1 million fibers each 15 microns in diameter (Fig. 3). Experimental tubes

(*Continued on page* 527)

• FIBER GLASS •

EQUIPMENT & SUPPLIES

FIBER GLASS SCREENING for windows, screens, porches, breezeways, patios and pool enclosures is guaranteed against denting, shrinking, corroding, and rusting and resultant sidewall stain for 10 years. It is made of vinyl-coated fibrous glass yarns in several weaves. Guarantee is based on the company's laboratory testing and field exposure.

PIPE INSULATION. High temperature insulation with ripple-textured protective aluminum jacket for industrial piping. Longitudinal seam of the jacket snaps together with interlocking lips in one step; end joints are sealed with a band containing an integral sealing compound. Easily removed for inspection and repair. Manufactured in pipe sizes from ½" to 24 inches with 1-inch to 3-inch thicknesses. Copper tubing sizes are from ½" to 3 and ⅛-inches, OD, with thicknesses of 1 and 1 and ½-inches. Effective to 1,200°F. or 1,800°F.

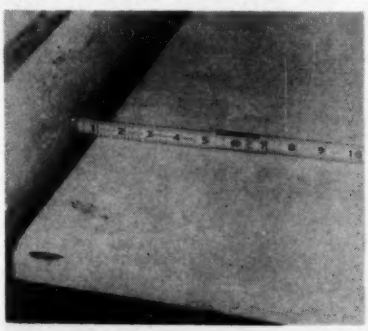
Owens-Corning Fiberglas Corp., 717 Fifth Ave., New York 22, N.Y.

APPLICATIONS

FIBER GLASS FLAT BOARD is being used as a vibration dampener. In one instance 10,000 sq. ft. of fiber glass board, 4" thick, was placed under the concrete slab of a building housing delicate instruments and in which critical laboratory experiments were to be performed.

In a recent plant expansion which required a vibration-free room, for a three-fold increase in the size of telephone facilities, resin-bonded fiber glass molded into flat board shape was again used. The room, 18 ft. x 20 ft. was directly above two steel rolling mills and a 10 ft., ¼" Cincinnati shear. The problem was not only to provide flooring to support the telephone equipment but also to dampen outside vibrations and vibration transmission through the wall. To accomplish this the 4" thick fiber glass board was cemented over the original ¼" plywood floor which covered the basic subflooring. The fiber glass board was in turn covered with ¾" plywood and upon this linoleum was laid. A space of 1" was allowed between the walls and the edges of the new flooring (See photograph) to eliminate transmission of vibration through the walls.

Fibrous Glass Products, Inc., Hicksville, N.Y.



EPOXY ENCAPSULATED INSULATION SYSTEM on open weatherproof A.C. motors comprise a new line of equipment from Reliance Electric and Engineering Company. The system employs polyester round copper magnetic coil wire, epoxy-insulated glass fiber sleeving, epoxy-treated glass fiber cloth slot liners and phase insulation. Glass mat base epoxy resin laminate protects the separators and top sticks. The stator windings and bearings are thoroughly encapsulated in a specially formulated epoxy resin for resistance to moisture, oils, dust, chemicals, acids and alkalies.

Reliance Electric and Engineering Co., 24701 Euclid Ave., Cleveland 17, O.

EPOXY TEST KIT for permanent adhesive for fiber glass, glass, ceramic, metal, and other materials for the aircraft, electronics and other industries. Test sampling kit is free and contains equal 50/50 quantities of epoxy resin and hardner.

Fybrglas Industries, 3010 W. Montrose Ave., Chicago 18, Ill.

FIBER GLASS LEADWIRE INSULATION is used on a new line of magnesium-oxide packed thermocouples for applications involving melt furnaces, gases, nuclear reactors, liquid metals.

Barber-Colman Co., Rockford, Ill.

FIBER GLASS CHOPPED STRAND MAT with superior wet out qualities. Claimed to wet out 3 to 5 times faster than other products now in the field; to be more uniform in fiber distribution and weight; and to have a pure-whiteness that will impart no off-color to finished laminates. Benefits are increased production speed and better end-product quality.

Made of continuous filament fiber glass roving to which a Garan binder has been applied, the roving is chopped into lengths of approximately 2 inches. It is then formed into a mat with random pattern and bonded with plastic resins.

Faster wet out cuts production time in the making of laminates by reducing the amount of rolling and brushing required by the operator. The finished laminate has a smoother surface because no individual fibers are picked up in the rolling-brushing process.

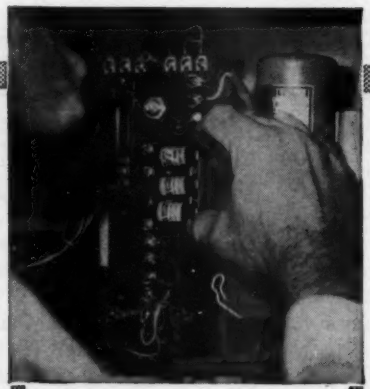
Photograph shows Garanmat (left) and ordinary mat (right) after 11 seconds soaking in polyester resin. Countdown clock works in reverse. (Hand moves counterclockwise.) The black strips beneath are beginning to show clearly through the Garanmat indicating its wetting out qualities.

Presently available in weights of 1¼, 1½, 2 and 3 ounces per sq. ft., and in widths up to 76". It will be available in ¾, and 1 ounce weights in the future.

Johns-Manville Fiber Glass Corp., Toledo, O.

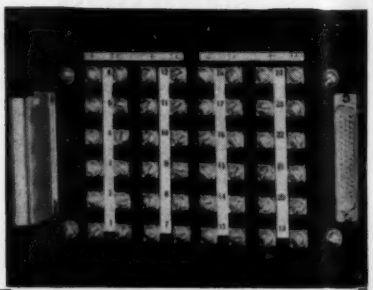
Record 2 to 24 points on the same

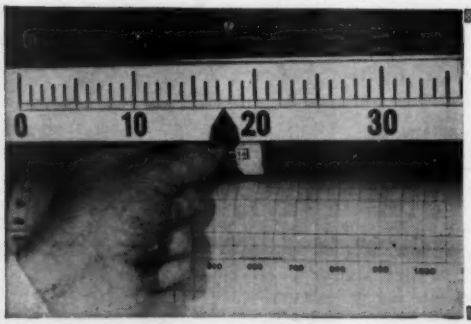
UNIVERSAL Electronik RECORDER



CHANGING RANGE IS EASY—Loosen screws and slide out the range resistor card. Replace with a different card, tighten screws and the job is done quickly and easily.

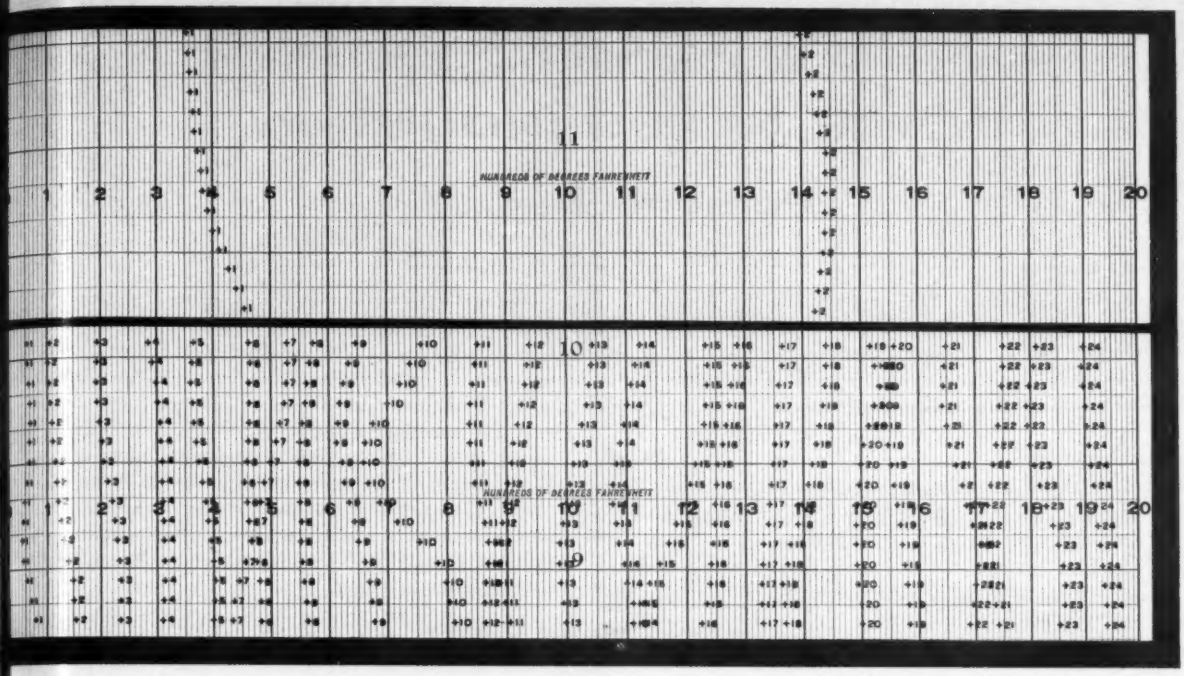
New modular design . . . and greater value than ever





CHANGING NUMBER OF POINTS IS EASY—First, remove thumb-tight nut; slip off print wheel and indicator dial. Slip on new wheel and dial and replace nut. Second, replace one plug-in unit on extreme right of terminal board, and the instrument is ready to record any desired number of points.

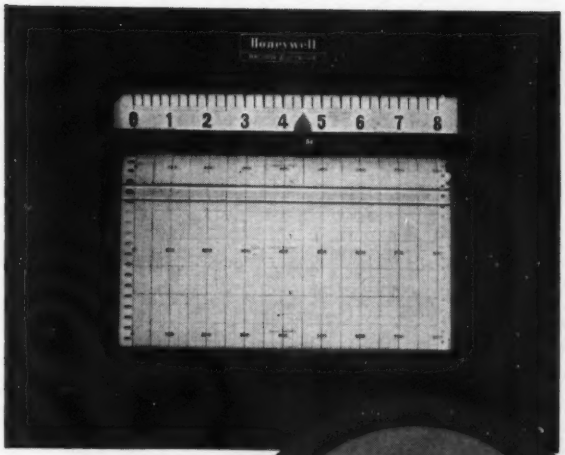
CHANGING COMPENSATION IS EASY—Input terminal board comes out by removing one plug (extreme left) and four screws. Slide in the new board, replace the screws and plug and the compensation is changed. Reference junction is built into terminal board on reverse side.

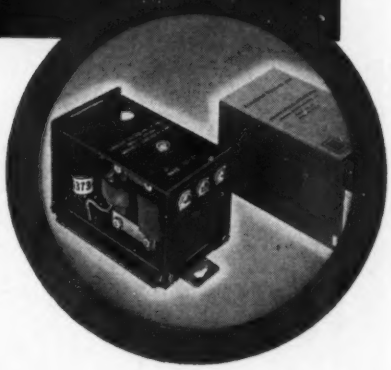


Now, you can record 2,3,4,6,8,10,12,16,20 or 24 points on one instrument—the new Universal *ElectroniK* Recorder. And you can change the number of points to be recorded in a matter of seconds. It's as easy as this: remove a thumb-tight nut and slip off the old print wheel and indicator dial. Slip on a new wheel and dial and replace the nut. Plug in the number of points wanted, and the job is done.

New modular design makes all *ElectroniK* instruments easier to use and maintain and a greater value than ever. This new design has also resulted in substantial manufacturing economies and appropriate price reductions. Get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa.





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Honeywell

First in Control

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75th YEAR

PIONEERING THE FUTURE

NEWS
IN THE GLASS INDUSTRY

Personalities...

Robert S. King

Promoted to eastern sales manager Demuth Glass Works, Inc., Parkersburg, W. Va., subsidiary of Brockway Glass Company. Demuth manufactures glass vials and specialized containers that are fabricated from machine-drawn glass tubing.

Ralph B. Wentzel

Advanced to vice president in charge of operations, Wheaton Glass Company. Harry Cowperthwaite is vice president in charge of sales and Roy S. Brown, Jr., is now manager of the company's New York Regional Sales Division.

Paul N. Perrot

Appointed director of The Corning Museum of Glass. He succeeds Thomas S. Buechner who was recently named director of the Brooklyn Museum. A native of Paris, France, Perrot studied in that country and also attended the Institute of Fine Arts at New York University. He began his museum career at The Cloisters, New York City, where he served as a research assistant and lecturer on medieval art. He joined the Corning Museum in 1954 as assistant director.

Dr. Alexander Silverman (right), receives a copy of a special brochure about the Silverman Glass Collection. The booklet was prepared and printed as a token of appreciation to Dr. Silverman for his generosity and continuing interest in Alfred University.

John R. Morehead

Appointed to the newly created position of manager of new product development, Owens-Illinois Glass Company's Glass Container Division. He will coordinate an expanded program by the Glass Container Division to develop new products and new uses for existing products. He will be succeeded as manager of the glass container plant, Charleston, W. Va., by Harold Ottesen, manager of the Atlanta, Ga., glass container plant. Mervyn M. Jenkins, now administrative manager of the glass container plant at Bridgeton, N. H., will succeed Ottesen as Atlanta plant manager.

Daniel T. Hardy

Succeeds John H. Goodwillie as plant manager, Libbey-Owens-Ford Glass Company, Shreveport, La. He began his career with the company's plant in Charleston, W. Va.

James E. Mambourg is assistant plant manager at the Shreveport plant. Other promotions: James E. Cross, chief machine operator; Homer S. Crump, superintendent of furnaces; and Claude H. Rambin, shift superintendent.

Van W. Bearinger

Director of Research, Minneapolis-Honeywell Regulator Company. Dr. Bearinger has been associate research director since 1956. John N. Dempsey and Edward E. Rexer have been named assistant directors.

Alexander Silverman

Honored by the faculty and administration of the State University of New York College of Ceramics, Alfred University. Dr. Silverman was presented with a 54 page brochure describing his Silverman Glass Collection which he gave to the College of Ceramics following his retirement from the University of Pittsburgh in 1951. President M. Ellis Drake of Alfred University presented the brochure. It contains 38 illustrations of selected pieces from the collection which has been termed the most representative of modern glass in the world from the standpoint of art and technology. The cover bears a color photograph of an enameled goblet from the table service of the last Czar. The text features a paper delivered by Dr. Silverman before the History of Chemistry Division of the American Chemical Society in 1956 outlining the history and origins of his glass collection. The booklet was prepared and printed as a token of appreciation to Dr. Silverman for his generosity and continuing interest in Alfred University.

Smith L. Rairdon

F. B. McGregor

Benjamin F. Post

Smith L. Rairdon

Elected executive vice president, Owens-Illinois Glass Company. He will continue to be responsible for marketing administration, purchasing, public relations, traffic, advertising, marketing development, and trade relations. Mr. Rairdon has been with the company since 1924. He has served as a salesman, division manager, general sales manager and as a director of Owens-Illinois Can Company, a subsidiary. In 1952 he was named vice president-marketing administration.

Allan W. Cox

Is supervisor of national distributor sales, Home Building Products Marketing Division, Owens-Corning Fiberglas. He has been with the organization since 1952.

Curtis A. Mewbourne

General superintendent of furnaces, machines and lehrs, Libbey-Owens-Ford Glass Company, Shreveport, La. H. Ross Meriwether, Jr., is now administrative assistant to Daniel T. Hardy.

Merle M. Eakins

General manager plate glass plants, Pittsburgh Plate Glass Company. Stephen Jeckovich is general manager, production services. H. W. Gardner is chief engineer, Glass Division, and Clifford H. Swensen and Thomas B. Jerman are assistant chief engineer and chief power engineer, respectively.

Ernest M. Levin

Received a U. S. Department of Commerce Silver Medal for Meritorious Service. The physical chemist with the Constitution and Microstructure Section of the National Bureau of Standards was cited for "very valuable contributions to phase studies by original research and for meritorious authorship." He is engaged in phase equilibrium studies of refractory oxide systems. The studies are performed to accumulate fundamental systematized data, usually in the form of phase diagrams, which can be applied, for example, to the development of ceramic bodies of desired chemical and physical properties.

F. B. McGregor

Has been appointed manager of abrasive products, Ceramic Division, Great Lakes Foundry Sand Company. He will head market research and sales of various types of abrasive products used in the ceramic and metal finishing industries. Benjamin F. Post has joined the Ceramic Division. He will be in charge of ceramic and abrasive product sales in the east.

Norman R. Tice

Textile glass products sales representative for Johns-Manville Sales Corporation in the New York area.

J. C. Denton

Elected director, Gustin-Bacon Manufacturing Company. He is also president of Spencer Chemical Company, Kansas City, Mo.

John Blaine

Tank superintendent at the Ottawa, Ill., plate glass plant of Libbey-Owens-Ford Glass Company. Lu-Verne F. McCallister is the new assistant tank superintendent.

Christopher H. Buckley

Named vice president and director of sales and marketing, Knox Glass, Inc. He was formerly general manager of the Aluminum Container Division, Kaiser Aluminum and Chemical Corporation.

Albert Garrone

Is chief engineer for Henry F. Teichmann, Inc., Pittsburgh, Pa., engineers to the glass industry. Other appointments are: Edward De Bald, chief mechanical engineer; Nicholas Brozenick, chief structural engineer; and Charles Seide, purchasing agent.

Sherman K. Reed

Named director of research, Chemical Division, Food Machinery and Chemical Corporation. Dr. Reed joined the company in 1950 and has held research positions with the Chlor-Alkali and Niagara Chemical Divisions. He is succeeded as research and development director by John A. Garman.

O'Mara White

Named regional sales manager of the West Coast area. Refractories Division, Carborundum Company.

Arthur W. Weber

Director of manufacturing services, Corning Glass Works. He is also a vice president. Dr. Ben Allen has been appointed director of engineering.

Melvin J. Oehlers

Has been promoted to assistant superintendent of the grinding and polishing department, Libbey-Owens-Ford Glass Company, East Toledo, O.

Bernard L. Hatch

Assistant to the vice president in charge of sales, Jeannette Glass Company

Companies...

Interstate Commerce Commission

Upheld Pittsburgh Plate Glass Company's appeal against increased freight rates on shipments of not-nested bent automobile replacement glass. The Commission's ruling is a gain in the company's six-year fight against what it considers unwarranted increases in classification ratings on automobile glass proposed by the motor carriers.

The distinction between ratings on not-nested and nested glass is removed and the Class 150 rating on less than truckload quantities of not-nested bent automobile glass has been cancelled. The old rating of Class 85 applicable to both nested and not-nested glass went into effect May 5th.

General Electric

Began construction last month on a $3-million plant for the manufacture of the basic silicone intermediate chemicals at Waterford, N. Y. The silicone intermediates chemicals will be processed into more than 250 forms of silicone, including silicone rubber, oils, fluids, resins, and specialty products.

Carl R. Megowen, president, Owens-Illinois Glass Co. (left), and Mayor deLesseps S. Morrison, of New Orleans, prepare to drive the first of 1,600 62-ft. pilings for the foundation of O-I's new ultra-modern, multi-furnace glass container plant located on the Industrial Canal in New Orleans. Their temporary employment as pile driver operators officially began the construction of the comany's 17th plant which will occupy 150,000 sq. ft. of a 24-acre site. Container production is expected by mid-1961.

American Can Co.

Is entering the glass container manufacturing field with the creation of its majority-owned subsidiary, The American-Wheaton Glass Corporation. Allied with the Wheaton Glass Company, Millville, N.J., manufacturers of pharmaceutical and cosmetic glass containers, and minority interest holders in the new company, American Can will start its first plants in Terre Haute, Ind., and Minneapolis, Minn.

In a letter to American Can Company's stockholders, William C. Stolk, chairman and chief executive officer, stated that the new company will have "plants strategically located throughout the United States as warranted by its volume of business."

Reichhold Chemicals, Inc.

And Nicolet Industries, Inc., announced through their respective presidents, Henry H. Reichhold and Guy George Gabrielson, Jr., that under the terms of an agreement between the two concerns, the control of Modiglass Fibers, Inc., had passed from Nicolet to Reichhold.

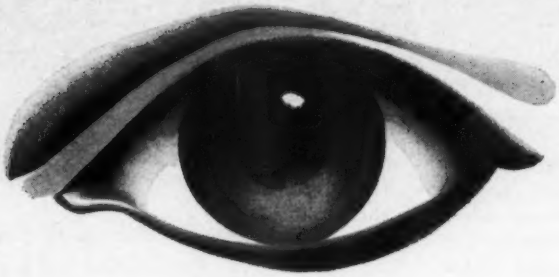
Nicolet Industries exchanged its majority of outstanding stock in Modiglass for an undisclosed number of shares in Reichhold Chemicals. Reichhold Chemicals is now directing the Modiglass operation and a new board of directors has been elected for Modiglass.

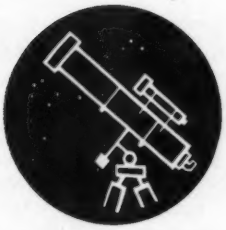
Modiglass manufacturers glass fibers and glass fiber mats for the reinforced plastic and other industries and has a plant and general sales office in Bremen, O.

A. O. Smith Corp.

Has developed and patented a new process for banding glass to steel in the manufacture of glass-lined water heaters, chemical vessels, glass-coated farm and industrial storage units and glass-protected steel smokestacks.

In the new process the steel is first treated with a special chemical spray or bath then finely ground glass is applied directly to the steel and fired at high temperatures. The result is a smooth translucent coating of glass with extreme resistance to corrosion, almost complete elimination of spalling or chipping of glass away from the steel surface, and the elimination of "fish scaling" caused by hydrogen. It is also possible to produce glass coatings on steel in a wide variety of colors.





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a subsidiary of Vitro Corporation of America
342 MADISON AVENUE, NEW YORK 17, N. Y.

inorganic chemicals and metals
Co Cu Ni Th U V Zr rare earths

Philco Corp.

Developed an experimental 18-inch, 122-degree rectangular shaped television picture tube, only 8⅞-inches deep, which lends itself easily to production. It is equivalent to standard 17-inch systems with respect to brightness, contrast, resolution and geometry; however, its deflection power requirements are less than normal 110-degree tubes. The shortest 17-inch, 110-degree tube now in use is about two inches longer than the 8⅞-inch model.

Molded Fiber Glass Body

Company, Ashtabula, O. will double its polyester resin production to 10 million pounds. Current construction designed to meet this goal is expected to reach completion by the fourth quarter of this year.

This year's total capital expenditures will amount to between $600,000 and $700,000 with $50,000 being invested in the research and testing laboratory. As of the three months ending May 31 the company showed a 170 per cent increase in profits before taxes and a 53.6 per cent sales increase. Profits for the three months of 1960 were $316,634 as compared to $117,299 for the same period in 1959. A wholly owned subsidiary, Molded Fiber Glass Boat Co., Union City, Pa., registered a 45 per cent increase in sales volume for the model year, September 1 through June 30. This is a $290,000 increase over the same period in 1959.

Armstrong Cork Co.

Increased its glass container production at the Dunkirk, Ind., plant with the installation of a new end port type glass melting furnace. The electronically controlled furnace has increased production capacity by 50 per cent and is the third glass melting furnace at the plant. Other new manufacturing facilities include six section forming machines, lehrs, carton and packing equipment, increased mold making equipment, new batch handling equipment, underground cullet handling systems, and added power services such as steam, gas and electricity.

A 144,000 sq. ft. warehouse is among the new storage and shipping facilities and brings glass container warehousing to a total of approximately 300,000 sq. ft. The expansion also includes complete carton making and handling facilities. In the shipping and receiving areas railroad sidings handle 34 cars at one time and truck docks can load a total of 45 trucks simultaneously.

Aerial view of Armstrong Cork Company's, Dunkirk, Ind., glass container plant. Lighter buildings at left are new warehouse additions. In the building with ventilators on top, (left and above the water tank), is the new glass melting furnace.

National Bureau of Standards

Construction will begin this year on the first three building units for the new NBS laboratories at Gaithersburg, Md. The first phase of this relocation program, for which Congress recently appropriated $23.5 million, will include an Engineering Mechanics laboratory, Radiation Physics laboratory and the power plant. Estimated cost of the entire program is $104 million and total relocation is to be completed in the period from 1962 to 1965.

Responsible for the relocation program are the critical research responsibilities assigned to the Bureau which demand modern laboratory facilities. The Bureau's present site, used since 1903, is too small for the expansion needed and the cost of modernization and renovation is prohibitive. An important point in the program is that the relocation is rural which eliminates interference of scientific progress with community life and vice versa.

Academy of Sciences

Of the USSR, Chemical Technology Section, in a forthcoming issue (Volume 129) reports a new technique for bringing about an overall increase in the strength of glass by combined chemical and thermal treatment. Experiments by scientists working at the D. I. Mendeleev Institute of Chemical Technology, Moscow, suggest the possible replacement of metals by glass as a structural material. The bending strength of glass treated by this new method is said to be greater than that of certain widely-used steels.

In the experiments industrial sheet glass was first softened by heating in a furnace to 200°C., then quickly immersed in a heated organosilicon liquid by steps of 20°. Since higher temperatures bring about considerable relaxation of the stresses established in glass the sheets were dried at 200° after removal from the bath.

The process increased the bending strength of 3 mm. thick glass by as much as 11 times, to 55 kg. per mm^2, while with thicker glasses the bending strength was increased by an even higher ratio. The marked increase in strength is due to the simultaneous hardening of residual stresses, and (at the moment of quenching) the formation of a silicon-oxygen polymer which heals the microcracks in the glass surface. The internal residual stresses produced in this way are only slightly greater than those produced in the normal hardening of glass in air. The success obtained depends on the nature of the polymeric film formed, which acts as a unique "armor", cementing the glass surface. The volume is translated by Consultants Bureau Enterprises, Inc.

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INVENTIONS AND INVENTORS

Glass Compositions

Glass Composition. Patent No. 2,892,726. Filed October 28, 1955. Issued June 30, 1959. No sheets of drawings; none reproduced. Assigned to Pittsburgh Plate Glass Company by John J. Smith and Earl T. Middleswarth.

This invention relates to a highly colored ultraviolet and infrared absorbing ophthalmic glass and it has particular relation to ophthalmic glass containing selenium and iron oxide in combination with glass forming oxides to produce a readily reproducible warm, rose smoke color in the glass.

Glasses with relatively low transmissions in the visible spectrum and with controlled absorptive properties in the ultraviolet and infrared regions are desired as overlays, or the like, in the ophthalmic field.

In accordance with the present invention, it has been discovered that if selenium and iron oxide are introduced into a lime-free base glass, which glass is essentially a soda-barium silica or soda-potash-barium-silica glass, highly colored glasses can be produced and the colors and absorptive properties can be controlled. When the combination of selenium with iron oxide is introduced into a properly compounded base glass containing mixed alkalis, barium oxide and silica, it has been found that although the infrared absorptive properties and the total luminous transmittance properties depend upon the oxidation-reduction balance of the melt, the color of the glass (due to absorption in the visual region) is insensitive to moderate changes of this type. This is especially the case with very dense glasses having a luminous transmittance of about 20 per cent at a thickness of about 1 millimeter and having a warm, rose smoke shade.

Examples of the glasses of the present invention and the ranges of the ingredients of suitable glasses are set forth in the table below wherein the percentages are by weight:

Table I

Ingredient	Compositions 1	2	3	Range
SiO_2	64.4	64.2	66.3	60-70
Na_2O	5.5	6.5	5.7	1-15
K_2O	6.3	6.2	6.4	0-8
BaO	12.3	12.3	12.6	8-15
ZnO	2.8	2.8	None	0.6
F_2	1.1	None	1.1	0-1.5
Fe_2O_3**	8.0	8.0	8.3	5-10
CoO	.014	.013	.015	0-.04
Se	.034	.033	.035	.01-.15
	100.448	100.046	100.450	
less O_2 correction*	0.4		0.4	

* Oxygen correction made for equivalent amount of fluorine where necessary.
** Presence of ferrous iron is acknowledged but ratio of ferric to ferrous iron has not been determined.

Sheet and Plate Glass

Glass handling mechanism. Patent No. 2,838,898. Filed May 31, 1952. Issued June 17, 1958. No sheets of drawings; none reproduced. Assigned to Pittsburgh Plate Glass Company by William Owen.

This invention pertains generally to glass handling mechanisms and, more specifically, to mechanisms for loading and unloading glass sheets into and from a suitable container or basket which carries the glass sheets in vertical position through an annealing lehr.

In the continuous manufacture of window glass, the molten glass is withdrawn from the melting furnace and passed vertically upward through a series of rolls until it has cooled and is then cut to size. For some purposes it is desirable to anneal the glass. In order to avoid marring the face of the glass sheets, it has been found desirable to pass the glass sheets in a vertical position through the annealing lehr.

Also, when loading the sheets of glass in the annealing basket, it is desirable that the sheets be positioned substantially vertical in the basket to avoid distortion of the sheets during the annealing process and to also space the sheets horizontally in the basket to affect uniform heating and cooling of the sheets as the basket passes through the annealing lehr.

A loading mechanism having an automatically operated loading cycle, which is actuated by a reciprocating ram, is described. The loading mechanism starting from initial position will remove a sheet from the pack, position it within the annealing basket, and return to its initial position.

The loading device may also be readily modified or reversed in operation so as to be used for automatically unloading baskets and stacking the sheets in packs.

There were 8 claims and the following references cited in this patent.

United States Patents

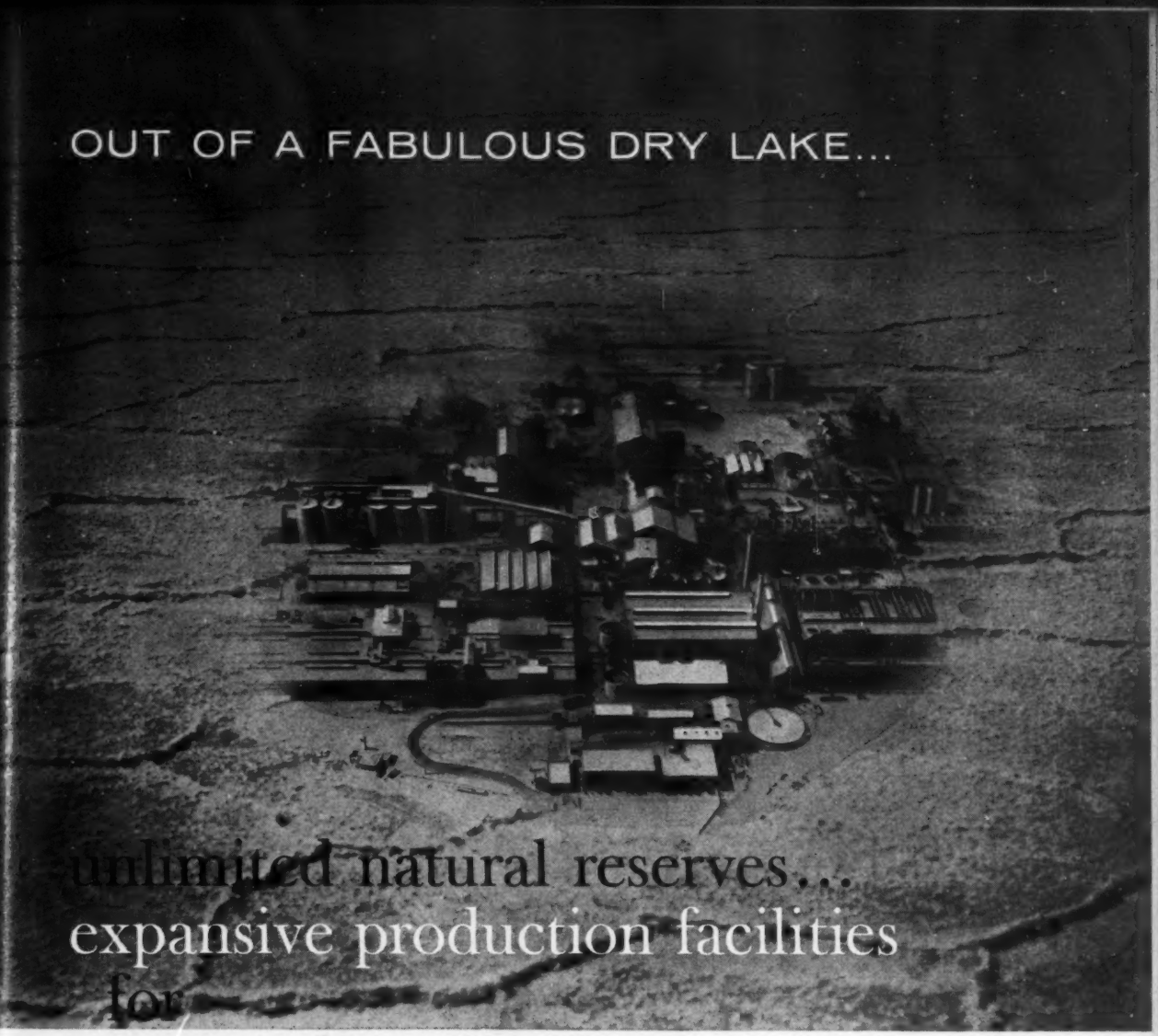
807,118, Kelly, Dec. 12, 1905; 864,053, Witherbee et al., Aug. 20, 1907; 980,004, Reeder, Dec. 27, 1910; 1,021,710, Stauft, Mar. 26, 1912; 1,412,568, Mortensen, Apr. 11, 1922; 1,959,216, Owen, May 15, 1934; 2,049,850, Lytle et al., Aug. 4, 1936; 2,524,846, Socke et al., Oct. 10, 1950; and 2,541,045, Fermerda et al., Feb. 13, 1951.

Tube and Cane Machines

Glass sealing. Patent No. 2,876,596. Filed November 28, 1955. Issued March 10, 1959. No sheets of drawings; none reproduced. Assigned to Radio Corporation of America by Sebastian W. Kessler, Jr.

This invention is directed to the use of aluminum or an aluminum alloy as a soldering material between the

OUT OF A FABULOUS DRY LAKE...



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glass envelope parts for an electron discharge device. The advantage of using aluminum is that aluminum in its melted state wets glass very well. Also, aluminum with a melting point close to 660°C remains stable during tube processing procedures during which the tube parts are baked around 400°C. However, the melting point of aluminum at 660°C is above the softening points of soft glasses commonly used in bulb fabrication such as the Corning 9012 glass with a softening point of 628°C and the Corning 9010 glass having a softening point of 650°C. To prevent the distortion of glass parts at the melting temperature of aluminum it was found, in accordance with this invention, that a successful sealing method can be followed by pressing an aluminum foil between the glass surfaces to be joined at high pressures and at temperatures lower than the melting point of aluminum and the softening point of the glass. This sealing technique which combines the use of pressure with relatively low temperatures was found to give reliable results, and successful seals were consistently made. Aluminum appears to join to glass by a diffusion method in which aluminum atoms replace silicon atoms in the structure of the glass.

There were 9 claims and the following references cited in this patent.

United States Patents

1,724,645, Engels, Aug. 13, 1929 and 2,110,900, Zimmermann et al. Mar. 15, 1938.

Other References

Ser. No. 414,756, Long (A. P. C.), published April 27, 1943.

Glass and Wool Fiber

Composite Steel and Glass Fiber Spring. Patent No. 2,935,177. Filed June 13, 1957. Issued May 3, 1960. Two sheets of drawings; none reproduced. Assigned to Chain Belt Company by John M. Morris.

One of the difficult problems in connection with designing springs for structural elements, electrical equipment or vibratory equipment is to provide a material for the resilient members of the structure that is not only strong and highly resilient in itself but which is also immune to the action of corrosive vapors and other deleterious ambient conditions to which the equipment may often be subjected.

An improved spring comprises a relatively thin spring steel core faced on each side with a relatively thick skin composed of a plurality of layers of unidirectional high strength filaments, preferably of glass fiber, preferably laid parallel to each other and to the length of the spring and bonded to each other and to the steel by means of a hard resin adhesive.

There were 11 claims and the following references cited in this patent.

United States Patents

2,062,760, Overstrom, Dec. 1, 1936; 2,581,532, Hem, Jan. 8, 1952; 2,665,678, Bear, Jan. 12, 1954; 2,689,464, Wurtz, Sept. 21, 1954; 2,712,332, Annerhed, July 5, 1955.

Method and Apparatus for Forming Fibrous Glass. Patent No. 2,931,422. Filed October 26, 1954. Issued April 5, 1960, Eight sheets of drawings; none reproduced. Assigned to Owens-Corning Fiberglas Corporation by David M. Long.

This invention relates to an improved method and apparatus for producing fibrous glass. The apparatus utilizes centrifugal force for forming primary fibers and then the fibers or primaries are attenuated into much smaller diameter fibers by the action of a gaseous blast. The objects of this invention are attained by first forming a cylinder of fibers which passes downwardly from the forming section and then applying a liquid spray of binder or air-dispersed binder onto this cylinder. In certain forms of the apparatus further advantages are achieved as follows. The cylinder of fibers which tends to spiral slowly as it passes downwardly from the spinner is stopped from turning by use of air jets or jets of dispersed binder and then the cylinder of fibers is broken up as desired prior to collecting the fibers upon a suitable collection device.

There were 5 claims and 11 references cited in this patent.

Miscellaneous Processes

Electric welding glass parts. Patent No. 2,867,948. Filed January 12, 1954. Issued January 13, 1959. No sheets of drawings; none reproduced. Assigned to Owens-Illinois Glass Company by George Zimmerman.

In present day methods of electrically welding glass parts, wherein the electrodes are maintained at or close to the surface of the glass and wherein an arc is usually drawn, the intense heat applied to the exposed surface at the weld produces chemical and physical reactions which are not conducive to a perfect weld. The glass is raised to a high temperature at which it boils, forming bubbles or seeds within the glass and resulting in an imperfect weld. The exposed surface of the glass is also subjected to the chemical reaction, either oxidizing or reducing, induced by the atmospheric air and the gases of combustion employed for maintaining the high temperature, the result of which is an imperfect weld.

This invention comprises a method in which the surface portions of glass parts which are to be welded together are initially heated at the welding area to soften the glass, permitting the parts to be united and also permitting a pair of spaced electrodes to be projected into he softened glass. An electric current is then transmitted through the body of glass between the electrodes while the latter are immersed in the softened glass, thereby raising the temperature of the glass. Relative movement between the electrodes and the united glass parts provides a plowing action or movement of the electrodes through the glass. At the same time the glass at the welding area may be stretched and worked by moving the glass parts to and from each other.

There were 5 claims and the following references cited in this patent.

United States Patents

2,268,670, Ronci, Jan. 6, 1942; 2,389,360, Guyer et al., Nov. 20, 1945; 2,445,063, Guyer, July 13, 1948; 2,527,720, Guyer, Oct. 13, 1950; 2,590,173, Guyer, Mar. 25, 1952; and 2,680,332, Young, June 8, 1954.

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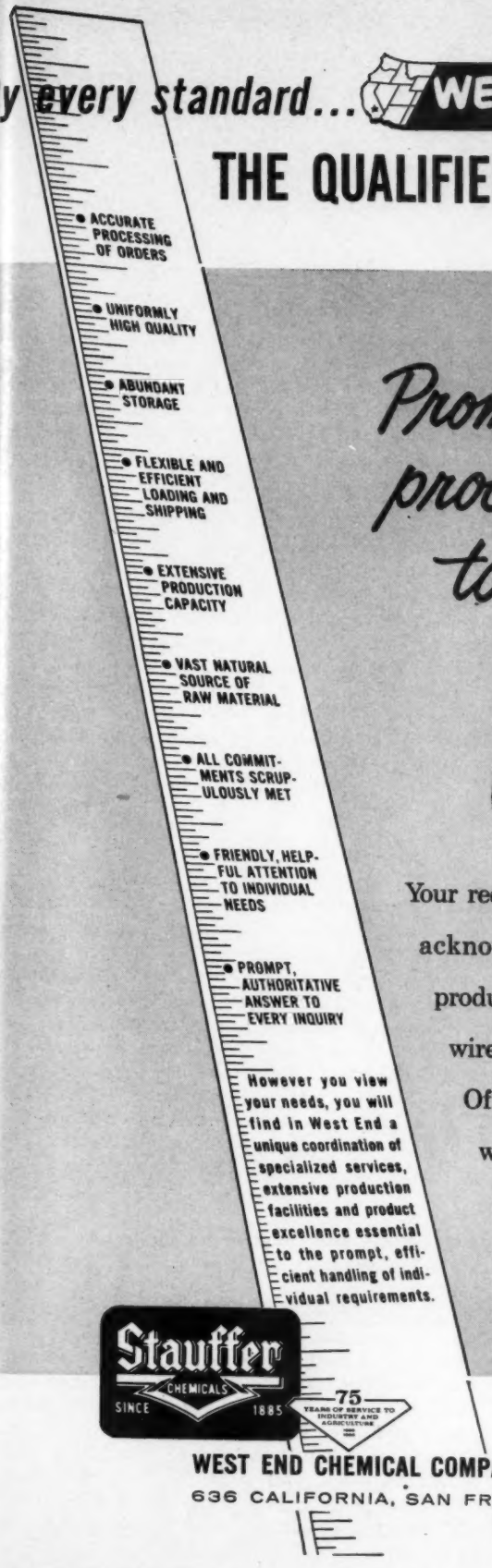
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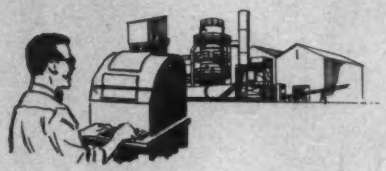

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CURRENT STATISTICAL POSITION OF GLASS

Employment in the glass industry during May, 1960, was as follows: *Flat Glass*: a preliminary figure of 26,600 for May, 1960, indicates a decrease of 7.1 per cent under the adjusted figure of 27,500 reported for April, 1960. *Glass and Glassware, Pressed and Blown*: an increase of 1.5 per cent is shown by the preliminary figure of 90,700 reported for May, 1960, when compared with the adjusted figure of 89,300 reported for April, 1960. *Glass Products Made of Purchased Glass*: the preliminary figure of 13,700 given for May, 1960, is identical to the 13,700 reported for April, 1960.

Payrolls in the glass industry during May, 1960, were as follows: *Flat Glass*: a decrease of 1.8 per cent is shown in the preliminary $14,440,649.76 given for May, 1960, when compared with April's $14,705,985.35. *Glass and Glassware, Pressed and Blown*: an increase of 7.7 per cent is shown in the preliminary $36,698,629.48 given for May, 1960, when compared with the previous month's adjusted $34,619,244.44. *Glass Products Made of Purchased Glass*: a preliminary figure of $4,342,337.62 was reported for May, 1960. This is an increase of 1.8 per cent when compared with the adjusted figure of $4,263,386.02 for April, 1960.

Glass Container Production based on figures released by the Bureau of the Census, Industry Division, was 14,806,000 gross during June, 1960. This is an increase of 9.5 per cent over the previous month's production figure, 13,514,000 gross. During June, 1959, glass container production was 13,778,000 gross, or 6.9 per cent under the June, 1960, figure. At the end of the first six months of 1960, glass container manufacturers have produced a preliminary total of 80,607,000 gross. This is 5.7 per cent more than the 76,227,000 gross produced during the same period in 1959.

Glass Container Shipments during June, 1960, came to 14,313,000 gross, an increase of 1.1 per cent over May, 1960, which totaled 14,151,000 gross. Shipments during June, 1959, amounted to 13,846,000 gross, or 3.2 per cent less than June, 1960. At the end of the first six months of 1960, shipments have reached a preliminary total of 77,001,000 gross, which is 3.7 per cent more than the 74,205,000 gross shipped during the same period of the previous year.

Stocks on hand at the end of June, 1960, came to 20,681,000 gross. This is 1.5 per cent more than the 20,358,000 gross on hand at the end of May, 1960, and 11.7 per cent more than the 18,509,000 gross on hand at the end of June, 1959.

GLASS CONTAINER SHIPMENTS

(All Figures in Gross)

Narrow Neck Containers

	June, 1960
Food	1,337,000
Medicinal and Health Supplies	1,272,000
Chemical, Household and Industrial	944,000
Toiletries and Cosmetics	912,000
Beverage, Returnable	1,280,000
Beverage, Non-returnable	198,000
Beer, Returnable	664,000
Beer, Non-returnable	1,467,000
Liquor	868,000
Wine	427,000
Sub-total (Narrow)	9,369,000

Wide Mouth Containers

Food	*3,891,000
Medicinal and Health Supplies	356,000
Chemical, Household and Industrial	178,000
Toiletries and Cosmetics	239,000
Dairy Products	131,000
Sub-total (Wide)	*4,795,000
Total Domestic	14,164,000
Export Shipments	149,000
TOTAL SHIPMENTS	*14,313,000

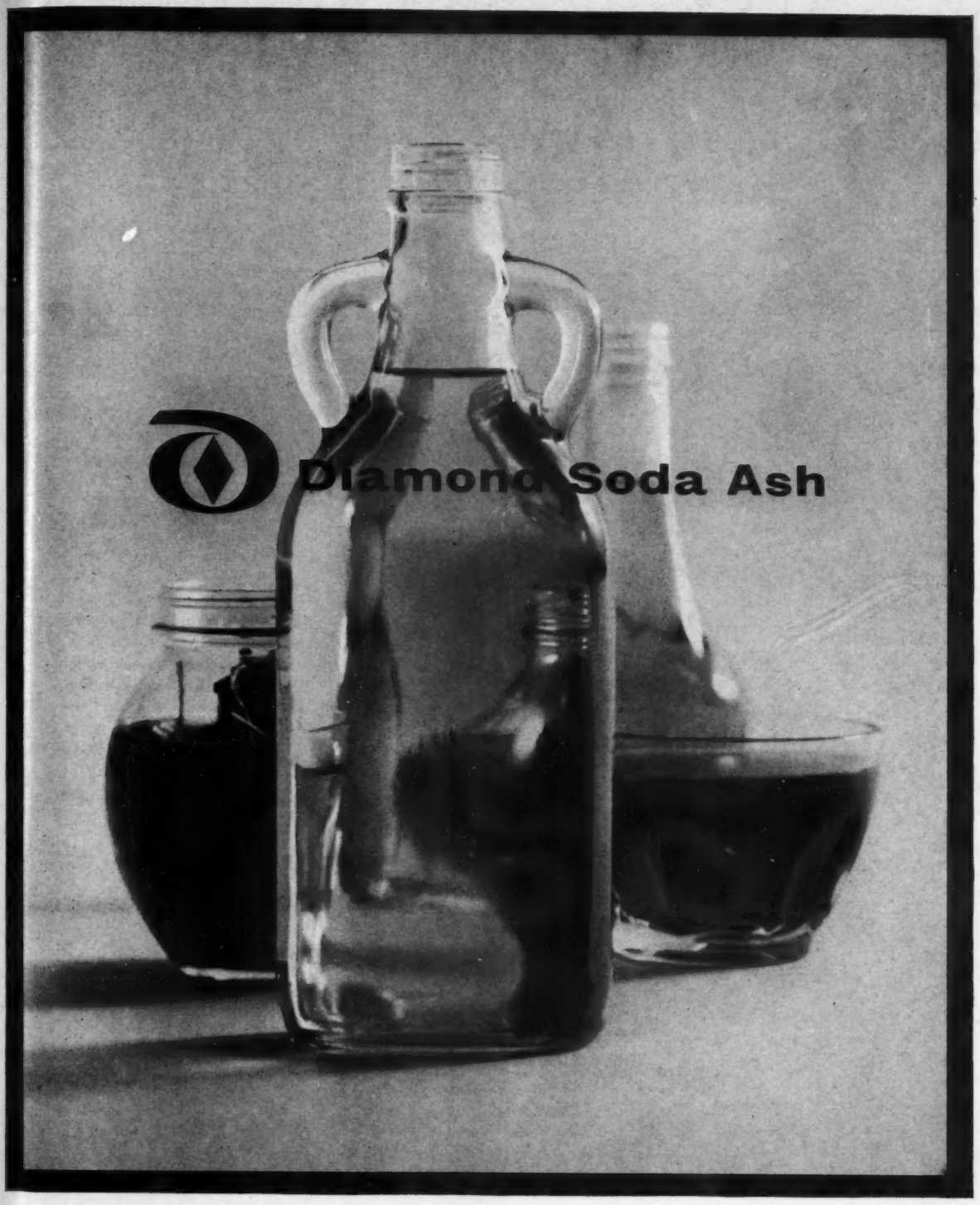
* This figure includes Fruit Jars, Jelly Glasses, and Packers' Tumblers.

GLASS CONTAINER PRODUCTION AND INVENTORY

(All Figures in Gross)

		Production June 1960	Stocks June 1960
Food, Medicinal and Health Supplies; Chemical, Household and Industrial; Toiletries and Cosmetics	Narrow Neck	4,912,000	7,393,000
	Wide Mouth	*4,995,000	*6,929,000
Beverage, Returnable		1,102,000	2,177,000
Beverage, Non-returnable		202,000	314,000
Beer, Returnable		686,000	550,000
Beer, Non-returnable		1,445,000	806,000
Liquor		880,000	1,419,000
Wine		457,000	731,000
Dairy Products		129,000	362,000
TOTAL		*14,806,000	*20,681,000

* This figure includes Fruit Jars, Jelly Glasses, and Packers' Tumblers.

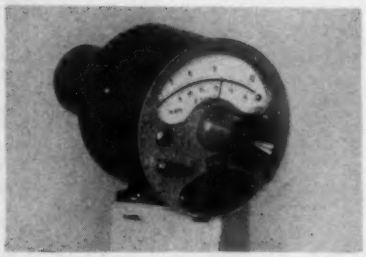


When you want uniform quality in glass containers, flat glass, pressed and blown ware, start with soda ash of proved uniformity.

DIAMOND ALKALI COMPANY, Union Commerce Building, Cleveland 14, Ohio

Diamond Chemicals

NEW EQUIPMENT AND SUPPLIES



Pyrometer

Device reaches its final position in 2 to 3 seconds where it can be button-locked for convenient reading. It has built-in temperature compensation and light intensity can be adjusted. No battery is used. Designed in several ranges for temperatures from 600°F to 3700°F. Weight 1 lb. 10 oz.

Epic, Inc., 150 Nassau St., New York 38, N.Y.

Glove Automat

Fuctions 24 hours a day as an automatic clerk, auditor, and glove depot. Wall-hung steel cabinet dispenses any type of work glove upon receipt of a special alloy token. Sensitive slug rejector and non-reset counter are included.

Arlington Industries, Inc., 1513 No. Shore Road, Revere 51, Mass.

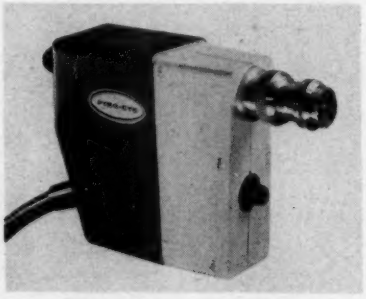
Dust Control System

For glass and ceramic plants using one mixer or two or more mixers when only one is run at a time. Approximately 1% moisture is applied to the material in the batch mixer. Dust is controlled from the batch mixer discharge through storage bins and up to and including charging the conditioned batch into the furnace. Moisture consists of one part of a surface active agent, compound MR, to 750 parts of water. Standard equipment includes a solution proportioning pump; 30-gallon mixing tank; electric contact meter, hand valve, strainer; solenoid control valve; solenoid pressure relief valve; flow differential control; and pressure switch.

Johnson-March Corporation, Philadelphia, Pa.

Optical Pyrometer

Available in two models: one for fixed mounting in production areas; the other is portable for laboratory use. Each can be used for completely automatic, continuous measurement and control of temperature in ranges from 1400°F to 4500°F and from 750°C to 2500°C. Temperatures can be measured from distances of 20″ to 60 ft. from the target. The temperature of an incandescent object is measured as a function of the difference between the object's radiant energy at two narrow band wavelengths within the visible spectrum. Since the spectral characteristics of radiant energy rather than the total magnitude of the energy are



utilized the pyrometer is relatively insensitive to unknown, varying or different emissivities.

Instrument Development Laboratories, Inc., 67 Mechanic St., Attleboro, Mass.

Laboratory Recorder

High-speed, high-sensitivity recorder to be used with recent chromatographic instruments for tracing complex gas chromatograms.

Fisher Scientific Co., 498 Fisher Bldg., Pittsburgh 19, Pa.

Grinder

High precision, centerless grinder with permanently mounted crush dresser designed for thrufeed, plunge feed, and infeed to their line. Includes coolant tank, and grinds glass, tungsten carbide, plastic and other materials.

Royal Master Grinders, Inc., 272 Highway 23, Riverdale, N.J.

Car Shaker

Uses a jib crane or fork lift truck for mounting anywhere along the length of the railroad car. A rotary vibrator transmits powerful vibrations throughout the car to loosen and shake compacted material through open hopper gates. It produces 900 vibrations per minute operating from 220 or 440 volt, 3-phase, 60 cycle a.c. power supply.

Syntron Co., 156 Lexington Ave., Homer City, Pa.

Refractory Brick

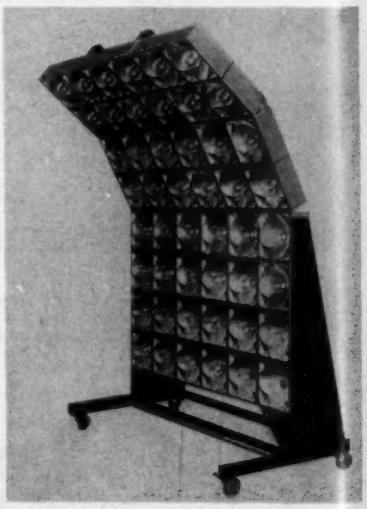
For continuous service at operating temperatures up to 2600°F. or more in ceramic and metallurgical furnaces. Material has unusual volume stability and load bearing ability at top operating temperatures, and excellent resistance to structural spalling.

H. K. Porter Co., Inc., Porter Bld., Pittsburgh 19, Pa.

Infrared Unit

Portable infrared unit that accomodates lamps up to 500 watts per socket with total possible connected load of 24 KW. It is suitable for wide variety of drying, heating and baking applications. The top four sections of the unit are adjustable to allow radiation to conform with product contours.

Fostoria Corp., Infrared Div., Dept. 19, 1200 N. Main St., Fostoria, O.



CATALOGS RECEIVED

Apparatus. (16 pages) Twenty-nine new items are illustrated and described including spectrophotometer, potentiometric recorder and nitrogen analyzer.
SCIENTIFIC GLASS APPARATUS CO., Inc., Bloomfield, N.J.

Combustion control equipment. (15 pages) Illustrated with diagrams and photographs. Installations for combustion control in the glass and steel industries' melting and heating furnaces.
MORGAN CONSTRUCTION CO., Combustion Control Div., 15 Belmont St., Worcester 5, Mass.

Micro-processing equipment. Bulletin presents precision-built units for removing solid, liquid or vapor contaminants from fluid systems in glass, ceramic, textile, plastic product. chemical and steel plants. Brief description and a cutaway is published for each unit.
SELAS CORP. OF AMERICA, Dresher, Pa.

Dust collectors. (6 pages) Illustrated, 2-color, bulletin describing new series 345 dust collector line. Design and construction principles are discussed; advantages of large tubes for high efficiencies and resistance to plugging are outlined; operating characteristics are explained by a cutaway section.
AMERICAN-STANDARD, Industrial Div., Detroit 32, Mich.

Chemical products. (36 pages) Brochure lists chemicals alphabetically, with physical data and uses.
FOOD MACHINERY AND CHEMICAL CORP., Chemical Divisions Advertising & Publicity Dept., 161 E. 42nd St., New York 17, N.Y.

Industrial water. (24 pages) Discusses range of industrial water problems from pre-treatment to waste disposal, and highlights the necessity for proper water management to obtain lowest water costs. Answers such questions as: Why is water the industrialist's most important raw material and Why can't the industrialist solve his own water problems? Cites case history examples describing process improvements resulting from more efficient uses of industrial water. Bibliography outlines over a hundred papers the company engineers have contributed to technical literature.
HALL LABORATORIES, Hagan Center, Pittsburgh 30, Pa.

Sodium Aluminate. (12 pages) Description of the industrial uses of sodium aluminate. Outlines how the chemical can be used in the glass and ceramic chemical processing.
NALCO CHEMICAL CO., 6216 W. 66th Place, Chicago 38, Ill.

Electrical instruments. (12 pages) Bulletin 19-60-61 lists each major line of electrical and speed measuring instruments. Includes insulations testers, frequency meters and tachometers.
JAMES G. BIDDLE CO., 1316 Arch St., Philadelphia 7, Pa.

Spraywelder. Bulletin. Illustrated in 4-colors. Gives a description of the unit and lists its advantages. Includes a step-by-step outline of the Sprayweld process.
WALL COLMONOY CORP., Detroit 3, Mich.

Automatic lubricator. (7 pages) Automatic valve lubricating system described along with instructions on installation and operation. Information is included on the unit's adjustment.
ROCKWELL MFG., CO., 400 N. Lexington Ave., Pittsburgh 8, Pa.

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NEW BOOKS

PATENTS AND INVENTIONS, AN INFORMATION AID FOR INVENTORS. (Pamphlet) Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. 25 pages. 15 cents.

This pamphlet is the result of many requests received by the U. S. Patent Office for basic information concerning patents, the Patent System and the operations and functions of the Patent Office. Its purpose is to provide independent inventors and others with information as to patenting and patent procedures to help them in deciding whether to apply for patents, how to obtain patent protection, and how to develop and market their inventions.

COATING FOR PROTECTING MOLYBDENUM FROM OXIDATION AT ELEVATED TEMPERATURE, by *E. S. Bartlett, H. R. Ogden,* and *R. I. Jaffee,* Defense Metals Information Center, Battelle Memorial Institute, for Office of the Director of Defense Research and Engineering. 45 pages. $1.25. Order PB 151064 from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

The report contains a comparison of the protective qualities of the more promising molybdenum coating systems and methods as an aid in selecting the proper coating for a particular application. Among the coating systems discussed are ceramic materials and refractory oxides. Examples of how some of these coatings have been applied to functional parts of molybdenum include: pitot tubes; thermocouple protection tubes; and in the glass industry, glass-bath heating electrodes and stirring rods.

RECLAMATION OF DIAMONDS FROM MACHINE WIPING CLOTHS, by *K. A. Jorczak,* Springfield Armory, U. S. Army. 11 pages. 50 cents. Order from Office of Technical Services, U. S. Department of Commerce, Washington 25, D. C.

Describes an improved process for the reclamation of industrial diamonds from machine wiping cloths. In the new system, one-pound lots of diamond-bearing cloths are put through an ordinary, portable-type washing machine, provided with a wire-mesh screen over a false bottom. Synthetic detergent is used. The residue from the first washing is fused in caustic KOH and $NaNo_2$ solution, cooled and dissolved in water. This oxidizes carbon and tungsten. Further washing rinses out the alkali before boiling in HCl concentrate. A bit of strong HNO_3 is added to complete oxidation.

The diamond particles are separated from the residue after it has been cooled and washed free of acid. Infused with thallous formate and subjected to steam baths, the liquid at a specific gravity of 3.5 releases its diamonds to the surface, where they float clear of other associated abrasives. The cloths are re-processed in the same manner, but in half-pound lots, and more diamonds thus gleaned. The accumulated diamond bits are finally dried and weighed on an analytical balance. Recovery is reported to be 95 to 99 per cent efficient.

GLASS IN SCIENCE AND INDUSTRY. 24 pages. Corning Glass Works, Corning, N. Y.

Illustrated booklet for students covers the use of various types of glass in medical and space research, industrial and food chemistry, and the electronics field.

Written in non-technical language for students in high school and the first year of college. The publication also covers the development of the electric light bulb; photosensitive glass; piping and laboratory apparatus; the 200-inch telescope mirror made for the Hale observatory; and Pyroceram.

BORATE GLASSES, by *L. Ya. Mazelev.* 166 pages. $10.00. English translation available from Consultants Bureau Enterprises, Inc., 227 W. 17 St., New York 11, N. Y.

A number of complicated problems in the chemistry, thermo-technics, and technology of glass manufacture, and the mechanization and automation undertaken by the glass industry have been solved successfully, but the problem of the structure of glass, especially that of borate glass, remains unsolved. This book contains all the available information on the structure of borate glasses and the effect of B_2O_3 on glass properties, together with the results of original research performed by the author. The purpose of the volume is to present the results of a systematic study of the technology of glass melting; the processes and reactions of glass formation; the crystallization of glasses and the composition of crystallization products; physicochemical properties and their relation to the composition and structure of glass and methods of calculating these properties. Text contains photographs, graphs, charts, diagrams, and a comprehensive bibliography.

PRINCIPLES OF OPTICAL CRYSTALLOGRAPHY, by *A. V. Shubnikov,* Director of the Institute of Crystallography, Academy of Sciences, USSR; Head of the Crystallography and Crystallophysics Department, Moscow State University. 186 pages. $9.50. English translation available from Consultants Bureau Enterprises, Inc., 227 W. 17 St., New York 11, N. Y.

Parallels the course on optical crystallography given at Moscow State University. However, descriptions of apparatus and experimental methods covered by introductory texts have been omitted. The chapters deal with basic ideas: the optics of isotropic transparent media, double refraction, interference of light in crystal plates, rotation of the plane of polarization, elliptical polarization and elliptical double refraction, conical refraction, and double absorption of light in crystals. Contains photographic, diagrammatic and tabular material integral with the text.

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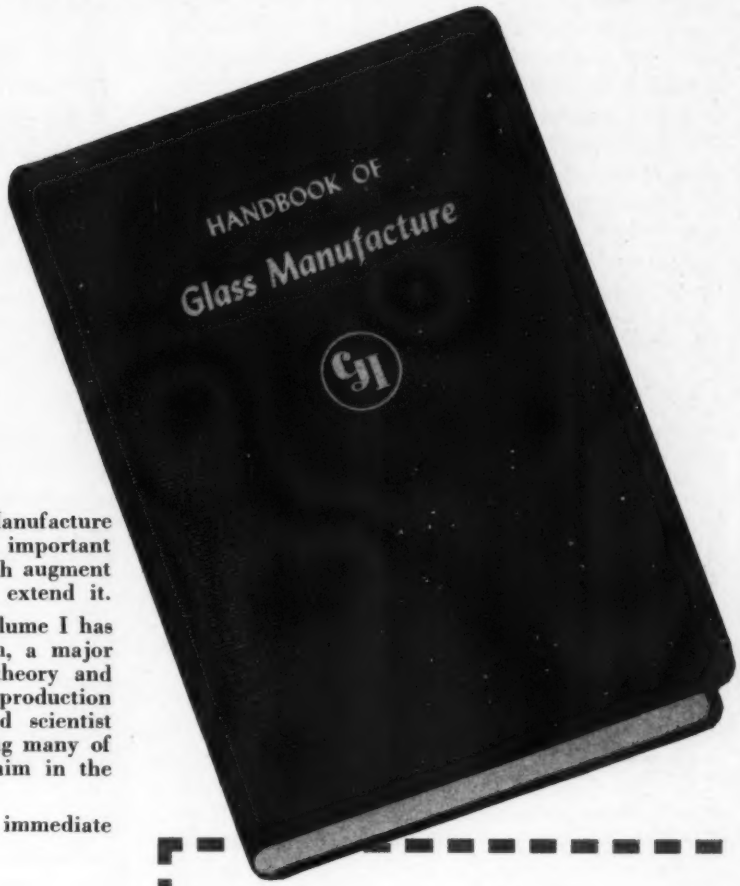
VOL. II
HANDBOOK OF GLASS MANUFACTURE



Volume II of the Handbook of Glass Manufacture deals with a number of significant and important topics in the glass industry, some of which augment the subject matter in Volume I, others extend it.

The basic purpose and philosophy of Volume I has been preserved in Volume II and, again, a major concept is to bridge the gap between theory and practice . . . and to provide for the production executive, the engineer, technologist and scientist an effective starting point for approaching many of the practical problems which confront him in the course of his work.

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CHEMICAL ANALYSIS OF GLASS
Francis W. Glaze, Consultant (A-D)
John Tims, *Owens-Corning Fiberglas Corp.* (E)

THE QUALITY CONTROL CHART
Ronald Wiley*, *Owens-Corning Fiberglas Corp.*

SCIENTIFIC GLASSBLOWING: GLASS FABRICATION
Vincent DeMaria, *Glass Products Development Laboratory*

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SILICONES IN FIBER GLASS

(*Continued from page* 501)

size removed by heat) alone, and with heat-cleaned glass plus *gamma*-aminopropyltriethoxysilane. It can be seen in Table II that such a coupling agent is necessary to insure retention of properties at high temperatures. One very important place where this retention is required is in missile nose cones which must withstand intense heat generated by atmospheric friction.

Epoxy laminates find wide application for printed circuits. Such laminates must maintain electrical and physical properties after exposure to the high heat of soldering and to acids used in the etching process. The recently developed filament winding technique is utilized with epoxies for manufacture of various convex structures from shot gun barrels to missile bodies. The silane in this case is applied in combination with a binder in the glass roving. The assurance of physical strength reliability imparted by the silane coupling agent in all of these cases is of utmost importance.

Melamine resins are used in conjunction with silane-treated glass for many electrical applications where properties must be maintained under wet conditions (See Table I-A). Satellites and missiles contain very delicate instruments and generally glass fiber lattice work is used to hold these instruments in place. To give these fibers great strength and heat resistance, silane glass finishes have been used.

Latest Developments

We have seen that silane coupling agents were originally developed for use with glass reinforced resin laminates, but their use is by no means restricted to these laminates. One new application is the use of *gamma*-aminopropyltriethoxysilane in conjunction with phenolic bonded glass wool batts which are used for thermal insulation. Such batts are compressed to less than one-half their normal size for shipping, in order to conserve space and cut shipping charges. They must return to normal size to be useful as insulation. If the bond between the glass wool and the resin is broken by degradation due to high humidity, this spring-back will not occur. The silane coupling agent very strikingly helps maintain this bond.

The latest development for silicones in the glass fiber industry is in an entirely new field, and concerns the Silrama Process, whereby decorative glass fabrics can be made with a wide variety of deep and rich colors. The silicones used in this process bond both the dyes and pigments to glass and achieve permanent colors which are not possible by any other means.

"Silrama" is Union Carbide Corporation's process for dyeing glass fiber fabrics which makes possible a panorama of new and brilliant colors and deep shades. It utilizes specially designed silicones developed by the company's research laboratories at Tonawanda, N. Y. By incorporating these reactive silicones into the dyeing process, it is possible to form a chemical union between the glass fibers of the fabric and the dye, or coloring pigment, by which the dye is locked onto the glass. It is therefore possible to obtain much deeper shades of coloring than in the past, and it is possible to use a much greater variety of dyes and pigments.

Gagliardi Research Corporation of East Greenwich, R. I., was Union Carbide's consultant in this development.

The Silrama process was tested on production equipment by J. P. Stevens & Co., Inc., at their Slater, S. C. plant, and pilot runs and control tests were completed by Owens-Corning Fiberglas Corporation at Ashton, R. I.

TOUGHNESS OF GRINDING SANDS

(*Continued from page* 486)

Considering the "pattern of particle breakdown", in the case of the slurry-ground samples, it can be seen in Fig. 7 that again a striking similarity exists between the fracture and toughness characteristics of the five sands. Not only do the curves in Fig. 7 appear to be identical, but, comparing Fig. 7 to Fig. 4, it can be seen that a similarity exists between treatments. Area increase data for the slurry-ground samples, plotted in Fig. 8, again show *Sand C* to be the weakest and *Sand B* to be the toughest, grain for grain.

Because of the similarities pointed out in the foregoing discussion and the proportionality constant which exists between the data of the two treatments, the selection of the relatively simple ball mill technique for future evaluations is considered justified (Table I).

Table I

Sand	% of −40, + 50 Mesh Particles Fractured (Ball Milled Sand)	% of −40, +50 Particles Fractured (Slurry-Ground Sand)	Ratio (% Milled) (% Ground)
A	54.1	22.1	2.5
B	44.3	16.2	2.7
C	69.7	34.3	2.0
D	56.8	24.8	2.3
E	46.1	16.4	2.8
			Mean = 2.5

The relative toughness of the four sands, as compared to the standard sand (*Sand A*) and as calculated for the two treatments in the manner described previously, is demonstrated in Table II.

Table II

Sand	Original Particle Shape	Toughness Factor (Ball Milling)	Toughness Factor (Slurry Grinding)
Sand B	Spherical	1.11	1.61
Sand E	Spherical	1.13	1.45
Sand A	Spherical	1.00	1.00
Sand D	Spherical	0.74	0.51
Sand C	Angular	0.63	0.31

Conclusions

Significant differences in toughness exist between silica sands, as indicated by the results of size reduction treatments applied to samples from varied geographical loca-

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Sometimes only competition—from other materials and other countries—can force a manufacturer to recognize that his equipment belongs in a museum and his unit costs wear high-button shoes.

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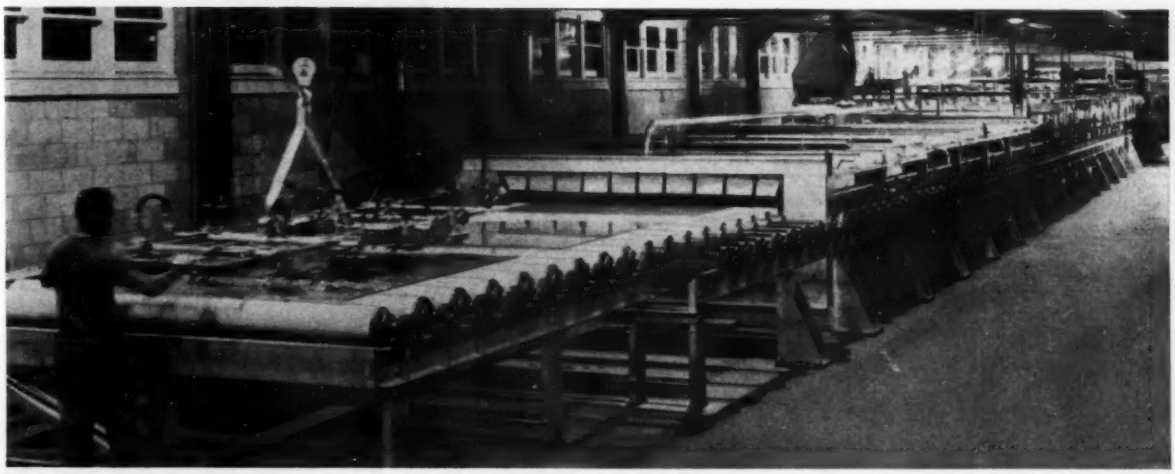

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tions and having different geological histories. Further, in the grinding of plate glass, spherical shaped grains are more resistant to fracture than are angular grains.

On the basis of the work presented in this paper, the ball milling technique offers a convenient means for determining the relative toughness values of a series of silica sands.

CONDITIONS OF GLASS FORMATION

(*Continued from page* 491)

The bond strength might be suspected of playing a role in glass formation, but it could be shown that Sun's treatment is based on arbitrary and illogical assumptions with respect to the coordination number. Dietzel's approach to the bond strength in ionic systems is more sound and reveals no relation between bond strength measured by the field strength of the cation and the ability of an oxide to form a glass.

With respect to the rules concerning glass formation based on the tetrahedral coordination one can only say that most commercial glasses fall within the scope of these rules but that the rules are not applicable to glass formation in a general way. Even if we limit ourselves to silicate glasses which contain only noble gas-like ions, the rules of Zachariasen are invalidated through the existence of Stevel's invert glasses.

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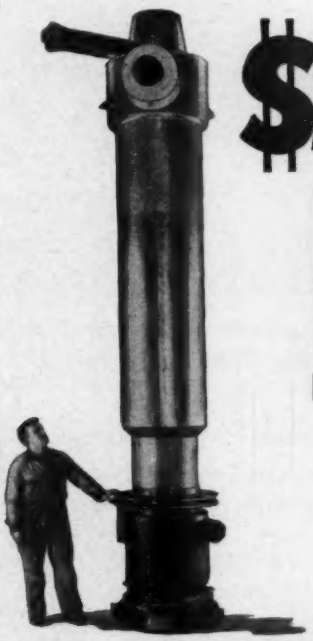

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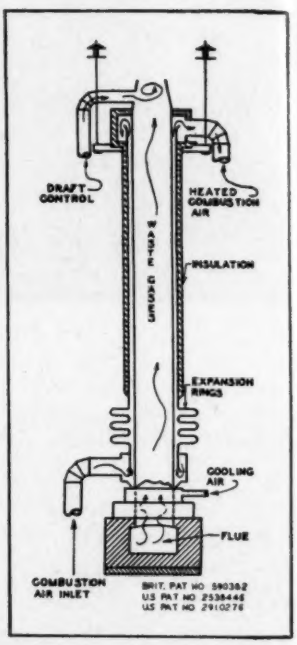

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LAMP MAKING MACHINE

(*Continued from page* 497)

in this inverted position, they are transferred to a basing machine.

As discussed above, bases are automatically fed into the basing machine except when a feeder senses the absence of a lamp. The bases already have been prefilled with a cement that will not set with reasonable exposure to air. Once the bases are applied to the lamp, fires play on the bases and set the cement. When the alcohol has been driven off from the cement, the leads are clipped and soldered at the side and at the eyelet. Then the lamps are seasoned according to a carefully determined schedule, automatically inspected for electrical characteristics, and finally, discharged down several chutes according to their classification.

All characteristics that may be inspected automatically have been checked at this point in the system; however, to conform to Westinghouse's high quality standards, it is necessary that visual inspection be conducted here for appearance, as well as legibility of the brand, price marking if used, and other details. The product is frequently removed all along the process for continuous quality control.

Once the lamps are completed, they are fed into an automatic conveying and packing system. The packing machine, owing to the amount of bulk material involved, is necessarily remote from the lamp making equipment itself. Therefore, the conveyor system is somewhat intricate and involves "traffic controls" and other refinements necessary to insure correct counts and continuous flow of material.

FIBER OPTICS

(*Continued from page* 504)

fitted with these windows had a resolving power capability of about 600 TV lines approaching the resolving capability of the tube itself. By placing the exit face of the flexible bundle directly against the fiber optics window on the vidicon a less efficient lens relay at this point was obviated.

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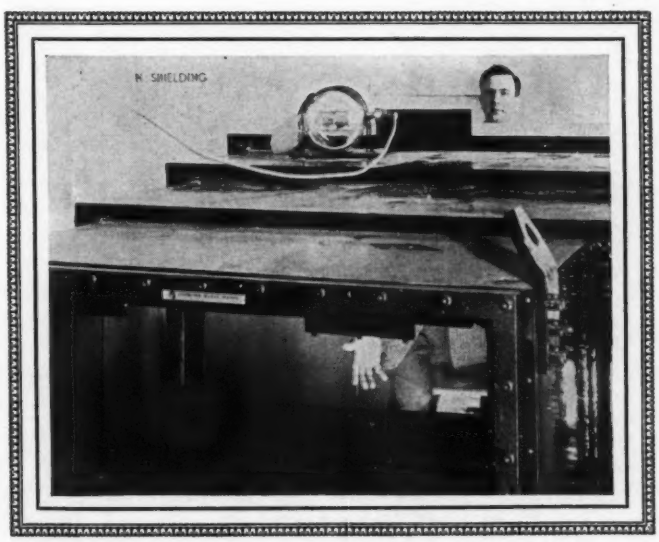

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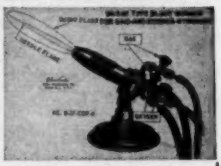

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In the second application described by Mr. Krolak, fiber optics was used in conjunction with an image orthicon type television camera tube to produce a high-resolution aerial reconnaissance system. In an existing form of aerial reconnaissance camera an image of the ground is photographed on a moving strip of film by continuous scanning through a slit. In the present application the photographic film in such a camera is replaced by a special assembly of optical fibers and an image orthicon tube. The fibers in the assembly are arranged in a single line at one end and in a group of short parallel lines or *open raster* pattern at the other end. This fiber optics *shape transducer* enables the image orthicon to record the image projected on a long narrow slit with much higher resolution than would otherwise be possible. Once again a fused fiber optics window is fitted on the camera tube to conduct light from the *raster* end of the *shape transducer* directly to the photocathode surface with higher optical efficiency than would be possible with a lens relay.

The information gathered by this pickup system would be transmitted by video to a receiving station. The station would be equipped with a special recording cathode ray tube having a fiber optics window (Fig. 4) and a similar *shape transducer* to reassemble the picture elements into a single image for printing out on a suitable photo-sensitive material such as Electrofax paper. Figure 4 shows a small experimental cathode-ray tube equipped with a fiber optics window. Mr. Krolak pointed out that the same principles could also be applied to a high-resolution, high-speed facsimile transmission system with which maps, mechanical drawings, etc., could be transmitted by video signals.

The third application described by Mr. Krolak involved another form of fiber optics *shape transducer* called an *image scrambler*. By deliberately rearranging the ends of the fibers at one end of a bundle with respect to the other end, it is possible to distort or render completely unrecognizable (i.e. "scramble") the transmitted image. Such a bundle can be used to encode and decode messages. In this particular application it provides a simple and inexpensive method for printing in coded form a depositor's signature on his bank passbook which can be quickly verified by the teller using a matching decoder at his window. This eliminates the need for separate signature files at each teller's location or constant reference to a central file. Since every teller of each branch of a large bank would have a decoder, it is necessary to produce a large number of identical units. To obtain this reproducibility a systematic rearrangement of the fibers rather than a completely random one is used. Many variations of fiber optics encoding are possible by systematically rearranging either individual fibers or groups of fibers. Mr. Krolak showed one form of scrambler which had been prepared to demonstrate the feasibility of this application.

Another approach to the facsimile problem was described by Mr. William Ross Aiken, Kaiser Aircraft and

Electronics Division, Kaiser Industries, Palo Alto, California. He has devised a novel cathode-ray tube of cylindrical form in which the image is formed along a straight line inside the wall of the cylinder parallel to its axis. One unique feature of this tube configuration is that the length of the line image may be made as long as desired up to several feet. The electrostatic deflection of the electron beam in the tube is achieved by multiple electrodes rather than a variable voltage as in conventional CRT's. To get the image from the phosphor layer inside the tube envelope onto a photosensitive material for facsimile recording purposes, Mr. Aiken proposed to use a special fiber optics window consisting of a long narrow array of fibers. Although, in principle, a single row of fibers would suffice in this application, several adjacent rows are preferred as they would allow some tolerance in the alignment of the electron beam. Although a tube of this type with a fiber optics window has not yet been built, both the basic tube and suitable fiber optics windows have already been produced, and only the sealing of the window into the tube needs to be worked out.

The application of optical fibers to the problem of another kind of character recognition, i.e. the automatic reading of printed matter for information handling, translation, etc., was discussed by Mr. Evon Greanias of IBM, Advanced Systems Development Division, Ossining, New York. The specific question he discussed was the ability of optical fibers to detect the characters on a printed page by reflected light. Studies on the distribution patterns of light radiated from various types of fibers have been made to determine the best conditions for obtaining a high signal-to-noise ratio in any proposed character recognition systems. No specific systems were described, but the use of fiber optics in this type of application is being actively considered.

Dr. Courtney-Pratt also reported on an application of fiber optics in high-speed sequence recording in addition to the theoretical analysis of the stray light problem he described earlier. He pointed out that it is very difficult to photograph certain highly transient phenomena such as explosions because of obscuring clouds of dust or smoke, but that this problem could be overcome by use of x-rays instead of visible light photography. In this case, the camera might consist of a fluorescent screen to convert the x-rays to visible light, a photographic plate, and a fiber optics bundle to act as both a mask and an optical coupling between the fluorescent screen and the plate.

The fiber bundle can consist either of an *open raster* (spaced rows) of fibers or an open grid of individually spaced fibers. In either case, it is possible to sequentially record at high speed a series of pictures on a single photographic plate by rapidly sliding the plate past the fiber bundle during the critical period to be studied. He has already demonstrated the feasibility of this approach using ultra-violet light in place of x-rays and a raster type fiber bundle of about one square inch in cross-section.

Dr. Kapany touched upon a number of other applica-

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tions of optical fibers, including potential uses in photographic objectives, astronomy, cathode-ray tube recording and medical endoscopy.

Medical Applications

Regarding the last of these, he showed slides of a medical-type flexible endoscope constructed at Armour Research Foundation and some colored photographs made through it, although these were not of a medical subject. Colors and details of the subject appeared to be quite faithfully transmitted.

In addition to the work reported by Dr. Kapany, a great deal is being done by several companies including American Cystoscope Makers, Inc., American Optical Company, and Bausch & Lomb, Inc. The goal of this activity is a series of instruments for the visualization and photography of many of the heretofore inaccessible recesses of the human body through the use of small diameter flexible fiber endoscopes. Instruments for examining the stomach, the duodenum and portions of the kidney have already been built. Ultimately, even the interior of the heart will be viewed by means of a slender fiberscope introduced through the blood vessels. Moreover, due to the small size and flexibility of such fiber endoscopes there will also be less discomfort associated with endoscopic examinations in general. For some of these applications fiber bundles of only 2-3 mm. in overall diameter will be required with individual fiber sizes down to 5 microns or less. The technology for producing such bundles is rapidly being developed along with the design and fabrication of suitable housings, objective lenses and means for manipulating the bundles within the body.

Additional Applications of Fiber Optics

Fiber optics in the form of non-image transmitting *light pipes* has already been used to illuminate hard-to-reach places and to transmit light to photodetectors.

As an example of the first case, a flexible fiber *light pipe* has been used to illuminate the interior of the stomach for gastroscopic observation. The level of illumination provided was sufficient to permit color motion pictures to be taken through the gastroscope.

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In the case of transmitting light to photodetectors, fiber bundles are being used in conjunction with photoelectric fire detectors in situations where the ambient temperatures are too high for the photoelectric cell, in particular, around jet aircraft engines. The same type of system can be used to detect flame-out in jet engines or in monitoring the burners in a large boiler installation. The flexible *light pipes* would view the flame area and transmit the signals to photocells located in a cooler zone.

By using two adjacent fiber *light pipes*, it is possible to illuminate an area with one of them and detect the reflected radiation with the other. A specialized form of reflection photometer can be built on this principle to measure the color, and thereby certain chemical properties of blood. By making the fiber bundles very small and fitting them into a suitable sheath (catheter) it would be possible to introduce the photometer probe into the heart chamber and monitor these properties continuously during surgery, etc. The same principle can be applied to other photometric problems where the reflecting surface or material is relatively inaccessible.

There is also a host of industrial applications for image-transmitting flexible fiber bundles. Wherever direct visual inspection in castings, weldments or complex machinery is made difficult or impossible by obstructions, blind cavities, etc., a flexible borescope could often be advantageously employed. Rigid type borescopes in a variety of sizes have been available for many years to examine deep bores, tubing, etc. The development of a similar line of flexible borescopes based on fiber optics is now technically feasible. A few instruments of this type have already been produced for specific applications. Combining a *fiberscope* with a television camera permits inspection of remote areas where neither system alone can reach.

A particularly awkward inspection problem for which fiber optics offers a possible solution is the examination of the long narrow channels in some types of nuclear fuel elements. These channels are so narrow in one dimension (about 1 mm. in some cases) that no ordinary borescope is suitable. A special optical scanning system incorporating long, thin ribbons of fibers as the illuminating and scanning elements, has therefore been proposed. Preliminary experiments have been run which indicate that this approach is technically feasible.

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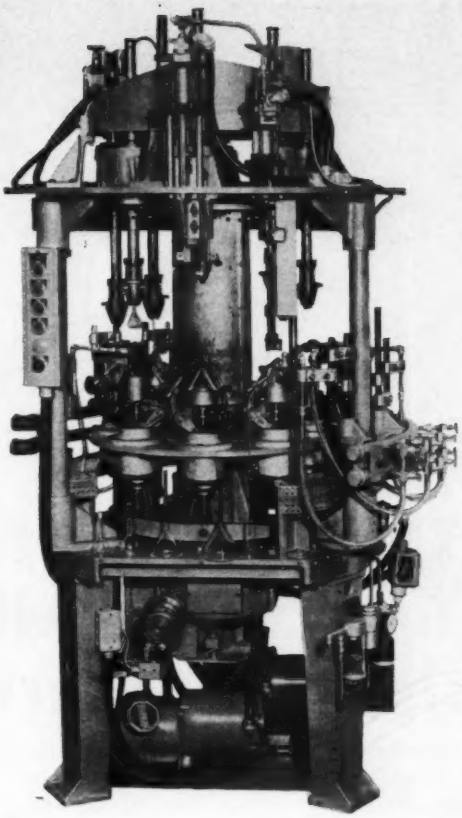

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